Berkas ini berisi mengenai 2 hal, yaitu:

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2. **Hasil cek similarities** pada karil untuk persyaratan khusus dengan judul “The Application of Synchronous and Asynchronous Learning using E-learning on Elementary Linear Algebra” (Page 233 – 256)

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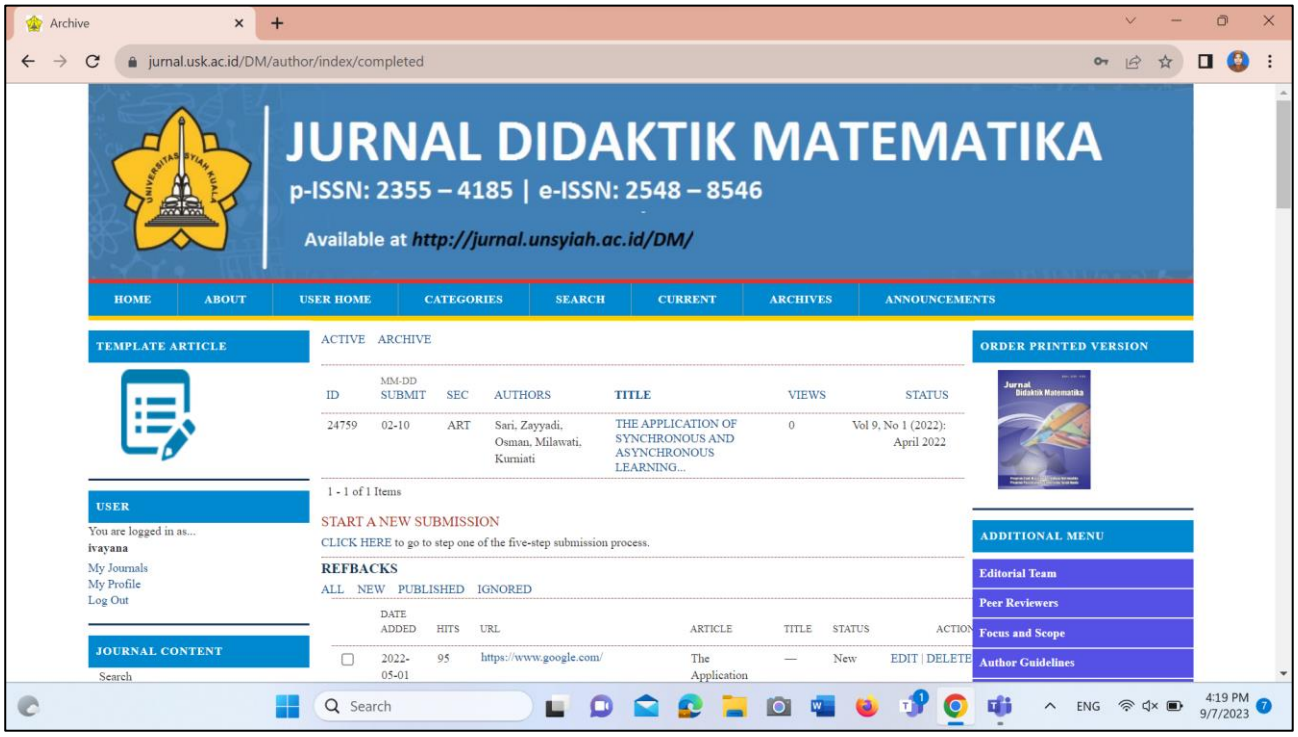
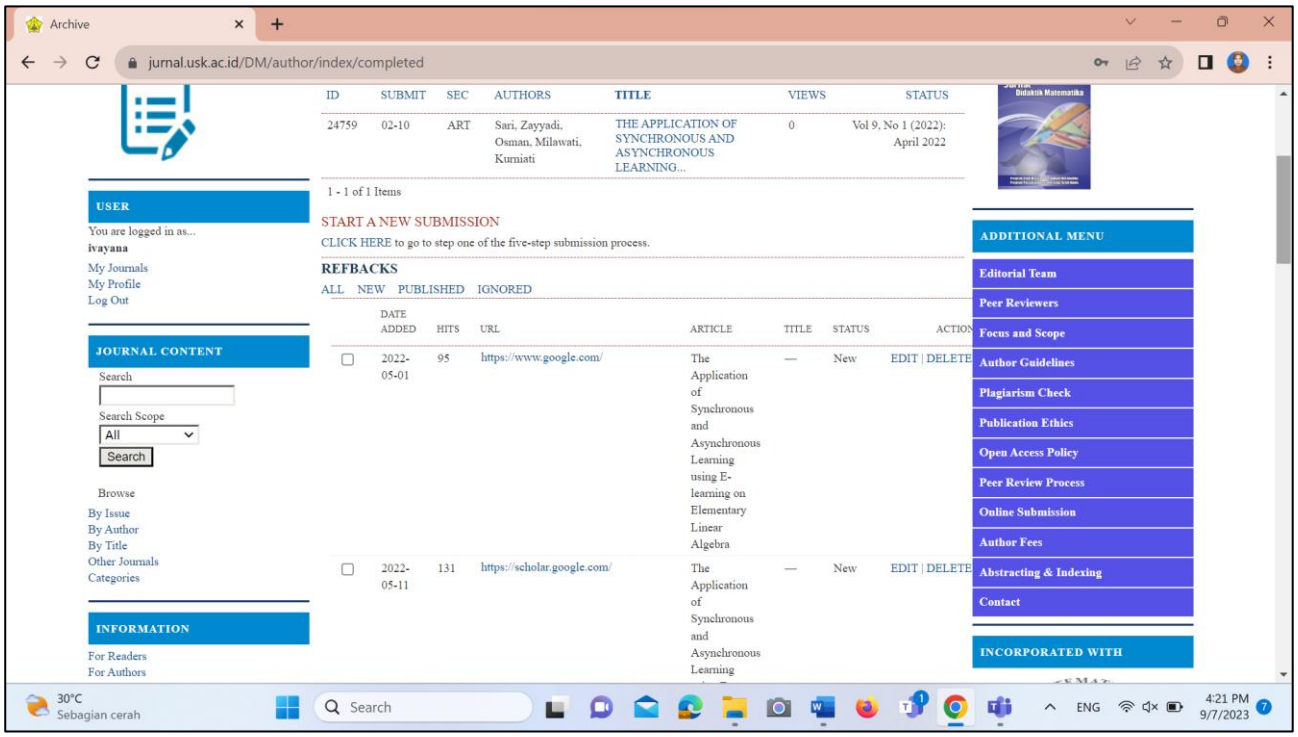
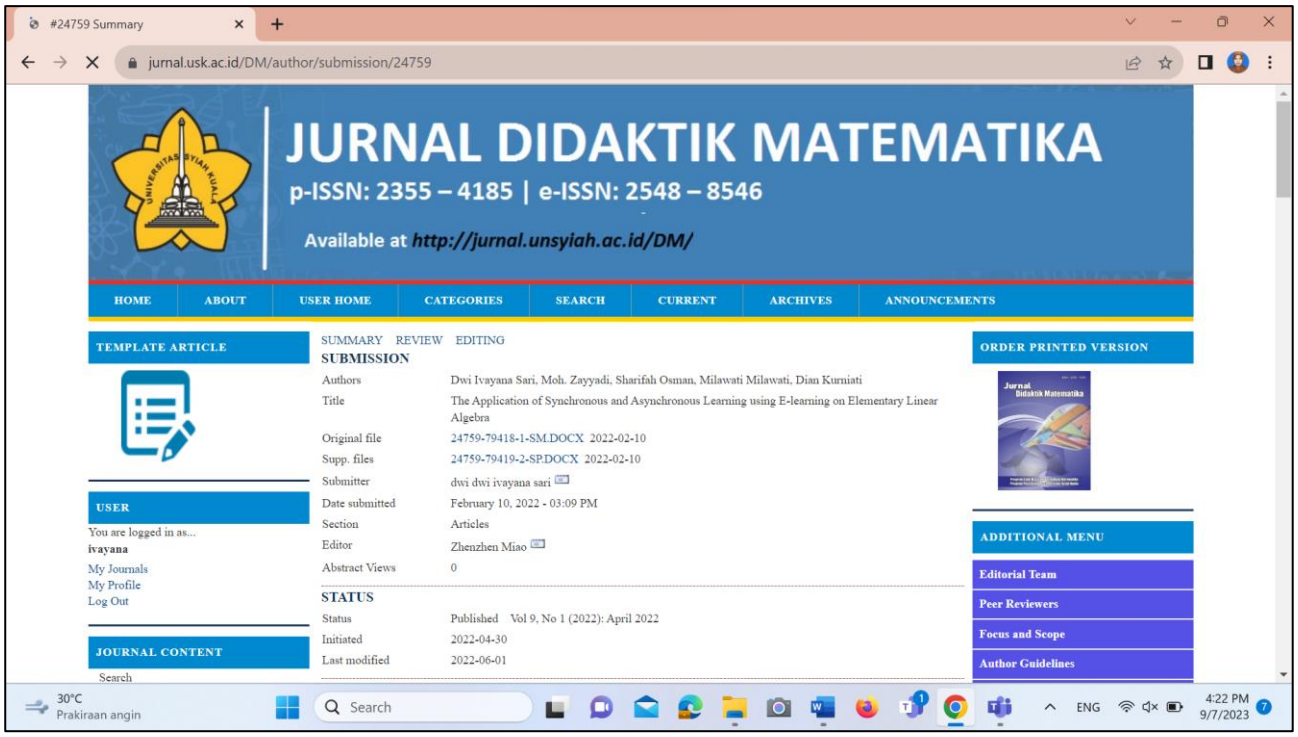
Judul: The Application of Synchronous and Asynchronous Learning using E-learning on Elementary Linear Algebra

Pengarang: Dwi Ivayana Sari, Moh Zayyadi, Sharifah Osman, Milawati, Dian Kurniati



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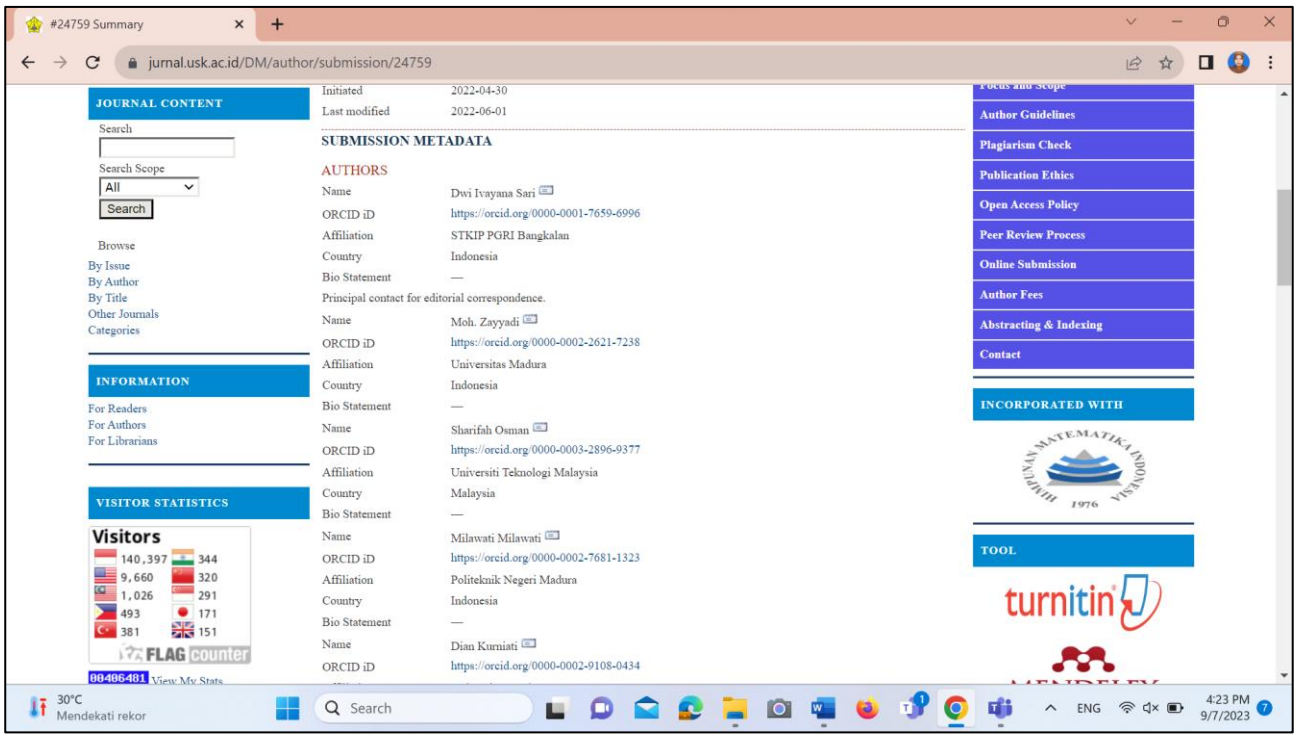
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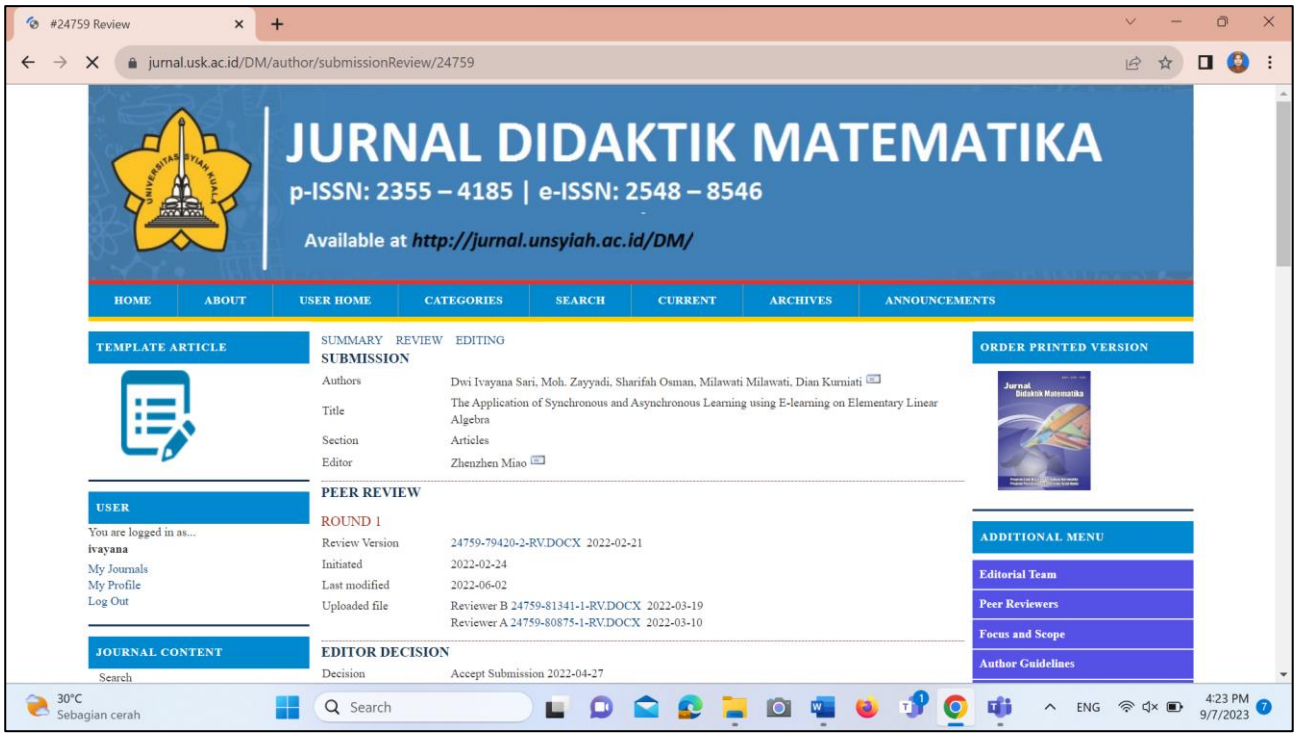
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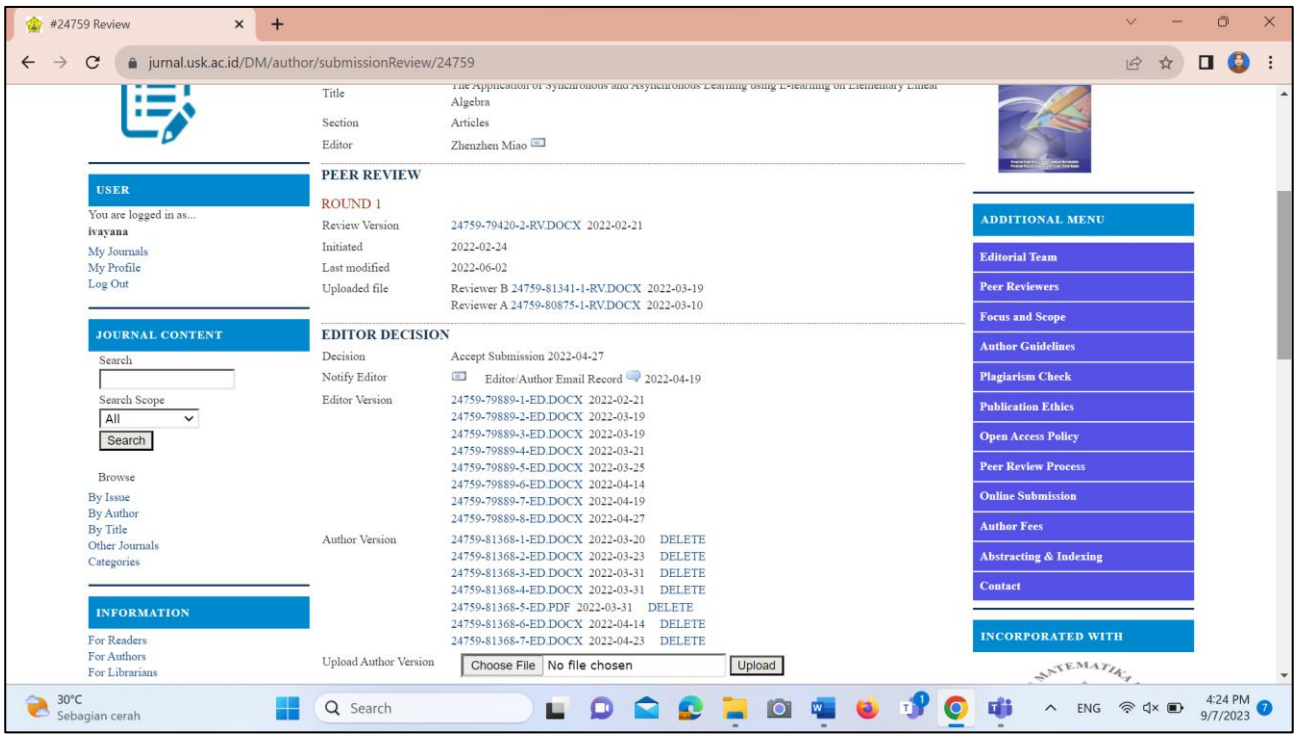
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Dear Authors/Contributors,
Thank you for your contribution.
We are pleased to inform you that your paper has been accepted for publication in the Jurnal Didaktik Matematika (JDM).
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Congratulations on the acceptance of your paper and thank you for your constribution and interest in Jurnal Didaktik Matematika.

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E-learning: Student's Perspective about Asynchronous and Synchronous Learning at Elementary Linear Algebra Material

Abstract. *Since the end of 2019, Indonesia had experienced a COVID-19 pandemic. It had changed the learning process from face-to-face to full-online. In early 2020, STKIP PGRI Bangkalan implemented online learning through WAG (WhatsApp Group). However, the learning result showed that 75% of students were not being complete in elementary linear algebra material. Online learning through Asynchronous learning by using e-learning with moodle platform was one solution to solve the problem. However, asynchronous learning needs to be combined with synchronous learning so that students can face-to-face virtual with lecturers. The purpose of this study was to determine improvement in students' learning outcomes and determine students' responses. The research design used was one group posttest-only design. 23 subjects were selected by clustered random sampling. Data were analyzed by descriptive statistical analysis. Results show that asynchronous and synchronous learning can improve students' learning outcomes. Results of the questionnaire showed that most students gave a positive response to asynchronous learning and synchronous learning.*

Keywords*: Asynchronous learning, synchronous learning, e-learning, elementary linear algebra*

Abstract. *Sejak akhir tahun 2019, Indonesia mengalami pandemic covid-19. Pandemic ini mengubah proses pembelajaran dari tatap muka menjadi fullonline. Di awal tahun 2020, STKP PGRI Bangkalan melaksanakan pembelajaran daring melalui WAG (WhatsApp Group). Namun pembelajaran ini mengakibatkan 75% mahasiswa tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui Asynchronous learning dengan memanfaatkan e-learning berupa platform moddle menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, Asynchronous learning perlu dikombinasikan dengan synchronous learning agar mahasiswa dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa dan respon mahasiswa. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa pembelajaran asynchronous dan synchronous learning dapat meningkatkan hasil belajar mahasiswa. Hasil angket menunjukkan bahwa sebagian besar mahasiswa memberikan respon positif terhadap pembelajaran asynchronous dan synchronous learning.*

Keywords*: Asynchronous learning, synchronous learning, e-learning, aljabar linear elementer*

Introduction

At the end of 2019, Word was shaken by emerging a new coronavirus called Novel Corona Virus (2019-nCoV). This virus was originally discovered in Wuhan China in December 2019. A very significant spread to all countries in the world occurred in early 2020, including Indonesia. This was the cause of the covid-19 pandemic in Indonesia.

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The covid-19 pandemic in Indonesia had a big impact in various fields, ranging from Health, Economy, and Education fields. In education fields, educational's institutions ranging from Kindergarten to Universities didn't implement face-to-face learning to reduce personal contact. Furthermore, Azhari & Fajri (2020) stated that to avoid the spread of Covid-19, the government gave the policy to close classrooms without stopping learning, so that schools implemented distance learning. Since 2020, learning had changed from face-to-face learning to online learning by using information technology (Rehman & Fatima, 2021).

In early 2020, online learning was implemented at STKP PGRI Bangkalan through WAG (WhatsApp Group). However, learning through WAG had many shortcomings, especially in an elementary linear algebra course. Based on learning outcomes data, it showed that 75% of students didn't complete studying. This means that 20% of students had completed studying. This learning outcome had decreased significantly compared to results of previous studies regarding the effectiveness of learning in an elementary linear algebra course, which showed that 86% of students had completed their studies (Sari, 2016).

Whereas elementary linear algebra course is a basic course that must be mastered by students because elementary linear algebra course is a prerequisite course for studying further courses such as abstract algebra. This is under the opinion of Suryaningsih (2016) & Ruswana (2019) who stated that elementary linear algebra was a basic subject that must be mastered by low-level students.

Based on the explanation above, online learning needs to be changed. It can be implemented by using asynchronous learning. Skylar (2009) stated that Asynchronous courses provide students with a flexible environment that was self-paced with students accessing course content using a variety of tools. Students were not restricted to a set day/time for communicating, and it allowed students more time to prepare a response to a set of directions or questions. Asynchronous learning is implemented by using the university's e-learning with moodle platform. According to Hambrecht in Ogbonna, Ibezim & Obi (2019) e-learning was defined as 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. E-learning contains content for one semester, are materials, discussion forums, and assignments. Yuhasriyati et.al (2020) stated that the use of e-learning may force educational processes to run faster in terms of accessibility and quality. The use of e-learning was also very influential on learning activities and students' learning outcomes (Fitriani & Nurjannah, 2019). Furthermore, Lin, Tseng & Chiang (2017) explained that students gave positive feedback on the use of Moodle learning platform for mathematics after experiencing blended learning.

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Before pandemic, e-learning can be implemented in blended learning, namely combining online learning through e-learning with face-to-face learning directly. There were several studies had shown that blended learning showed significant success in improving students' learning outcomes. As research results by Lin, Tseng & Chiang (2017) stated that ANCOVA and MANCOVA analyses showed that blended learning experience benefitted students in the experimental group by having a positive effect not only on learning outcomes but also on their attitudes toward studying mathematics in a blended environment. These results are in line with the research of Sukma & Priatna (2020) which explained that the implementation of blended learning in Mathematics had the potential to improve student's critical thinking skills (CTS).

However, during this pandemic learning was implemented fully online (Trenholm & Peschke, 2020), which means that learning was implemented using e-learning without face-to-face directly. Therefore, synchronous learning was an alternative to virtual face-to-face learning between lecturer and students. Shi & Morrow in Skylar (2009) stated that in real-time synchronous courses, the instructor leads the learning, and all learners were logged on simultaneously and communicated directly with each other.

Synchronous learning at STKIP PGRI Bangkalan was implemented by using zoom application, google meet application, etc. The aims of synchronous learning to students could understand the material so that student's learning outcomes were good. This is in line with the research results of Aisyah and Sari (2021) which stated that the use of the Google meet platform could improve students' learning outcomes.

Therefore, online learning using asynchronous learning through e-learning and synchronous learning through the virtual conference was an alternative in implementing elementary linear algebra learning. Many previous research results showed the success of asynchronous and synchronous learning. Research by Ogbonna & Ibezim (2019) showed that synchronous and asynchronous e-learning modes increased the cognitive academic achievement of students in word processing.

In the middle of 2020, STKP PGRI Bangkalan took a policy related to online learning implemented in 2 ways, namely asynchronous and synchronous learning. However, synchronous learning was implemented between 7-8 meetings. While asynchronous learning was implemented in full, namely 14-16 meetings. Asynchronous learning was implemented in e-learning classes, while synchronous learning was implemented in webinar classes (zoom, google meet, etc.).

However, this implementation’s change of online learning needs to be evaluated for its implementation. One of them was the student’s perspective because students were objects of

learning. Student success was the output of learning application by the lecturer. Based on this explanation, the aims of this study were 1) to determine the improvement of students' learning outcomes through asynchronous and synchronous learning in elementary linear algebra material and 2) to determine students' responses to asynchronous and synchronous learning.

Method

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Research Design

The author applied treatment to the participant's group, to determine the improvement of students' learning outcomes on elementary linear algebra material and students' responses to asynchronous and synchronous learning. Asynchronous learning was implemented in e-learning classes with moodle platform. Meanwhile, synchronous learning was implemented in the webinar class using zoom application.

The learning effectiveness was measured using two types, namely tests and a list of questions. Instruments were given to participants after learning implementation. The author applied to learn in one class by asynchronous and synchronous learning. Therefore, this study was an experimental study using a one-group posttest-only design.

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Participants

The population in this study was all students of the mathematics education study program at STKIP PGRI Bangkalan in the odd academic year 2021/2022, totaling 34 students. The author took a sample using clustered random sampling so that there were 23 students as a sample. The sample was heterogeneous based on gender and initial mathematical ability. Initial math skills were taken from calculus scores in the previous semester.

Instruments

Research instruments were lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of sixteen meetings, eight meetings were implemented in e-learning and webinar classes, eight more meetings were implemented in e-learning classes and WhatsApp Group (WAG), and then two other meetings were implemented for tests. The author implemented 8 webinar classes because it was under campus rules that implementation of synchronous learning through webinar classes was implemented 7-8 times, this was due to constraints in purchasing internet quota. In this case, the 8th meeting (mid-test session) and the 16th meeting (final-test session) were conducted in e-learning and webinar class.

Table 1. Activities of each meeting

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Meeting	Activities	Application
1	a. Students learn about linear equations and systems and linear equations in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
2	a. Students pay attention to the lecturer's exploration about Gauss and Gauss Jordan elimination through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
3	a. Students learn about matrix and matrix operations in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
4	a. Students pay attention to the lecturer's explanation about algebra properties of the matrix through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
5	a. Students learn about elementary matrices and methods to find matrix inverse in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
6	a. Students pay attention to the lecturer's explanation about solving systems of linear equations and inverse matrix properties through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
7	a. Students learn about diagonal, symmetrical, and triangular matrices in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
8	Mid-test a. Students download mid-test questions on e-learning b. Students did mid-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)
9	a. Students learn about determine determinants by cofactor expansion and row reduction in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
10	a. Students pay attention to the lecturer's explanation about determinant properties and Crammer's rule through zoom application b. Students discuss and ask if there is a concept that is not understood	E-learning class and Webinar class (zoom)

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	c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	
11	a. Students learn about vector space in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
12	a. Students pay attention to the lecturer's explanation about vector subspace through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
13	a. Students learn about linear combination and span in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
14	a. Students pay attention to the lecturer's explanation about linearly independent and linearly dependent b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
15	a. Students learn about base and dimensions in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
16	Final-test a. Students download final-test questions on e-learning b. Students did final-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)

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The author gives mid-test and final-test at the 8th and 16th meetings. Test questions were developed according to the material in the lesson plan.

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Table 2. 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 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 not both.	√			C2	Matrix	3	10
4	Given the system of linear	√			C3	Gauss Jordan	4	15

	equations, students can solve the system of linear equations using Gauss Jordan elimination			Elimination		
5	Given the system of linear equations, students can determine the coefficient value of one linear equation so that the system of linear equations, 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 inverse matrix by the inverse algorithm	√	C2	Inverse matrix	7	15
8	Given several matrices, students can determine upper triangular matrix, lower triangular matrix, and diagonal matrix	√	C2	Matrix	8	10

Tabel 3. 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 matrix determinant by using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system of linear equations 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 can determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that three 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 basis S of $M_{2,2}$ and students can determine dimensions of the S subspace of $M_{2,2}$	√			C3	Basis and dimension	8	10

The author developed a questionnaire to measure students' responses to the approach. The statements on the questionnaire used a Likert scale. Aspects of the questionnaire and indicators can be seen in Table 4.

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Table 4. Aspects and Indicators of The Questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	Student's knowledge of elementary linear algebra material through online learning
			Student's ability to understand every elementary linear algebra material through online learning
			Student's ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in Asynchronous and synchronous learning	Student's response when independently learning through learning resources in e-learning
			Student's responses when responding to discussion forums
			Student's responses when downloading assignments in e-learning, work it and upload answers in e-learning
			Student's responses about taking synchronous learning
			Student responses when discussing through webinar classes
			Frequency of students accessing e-learning
3.	E-learning dan Webinar classes applications	Ease of access and usefulness for students	Ease of accessing e-learning class application
			Ease of accessing webinar class application
			The usefulness of accessing e-learning class application
			The usefulness of accessing e-learning class application

The Procedure of Data Collection

Data collection was done by giving tests and questionnaires. The instrument was given online by using e-learning and google form. Learning implementation by using asynchronous and synchronous learning in line with lesson plan design.

Data Analysis

Data analysis in this study used descriptive statistical analysis because the aim was to explain and provide an overview of characteristics of a series of data, without doing any generation. After the test result data and student's response data were collected, authors analyzed data as follows:

1. Analysis of test result data

   Data analysis of test results was measured using a completeness test. This completeness test consists of an individual completeness test and a classical completeness test. The Ministry of Education and Culture categorizes students' scores into 5 categories as follows.

   $0 \leq$ score < 35 : very low
   $35 \leq$ score < 55 : low

55 ≤ score < 65 : medium
65 ≤ score < 85 : high
85 ≤ score ≤ 100 : very high

Furthermore, Widoyoko (2009) determines 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

Based on the criteria above, the author established criteria for individual completeness, namely that students were said to have completed learning if they got a score of 65% of the total score. While classical completeness criteria were 80% of students have completed their studies. Improved learning outcomes were achieved if students' learning outcomes after mid-test were higher than students' learning outcomes before being given treatment. Then students' learning outcomes of the final-test were higher than students' learning outcomes of the mid-test.

2. Analysis of student's response data

Student's response data obtained from questionnaires consists of 2 types. This was because questions from the questionnaire consist of 2 kinds, namely questions with 4 answers (1,2,3,4) and questions with 2 answers (yes and no).

For the first question, the criteria were as follows:

1, 00 ≤ average < 1, 50: less
1, 50 ≤ average < 2, 50: enough
2, 50 ≤ average < 3, 50: good
3, 50 ≤ average ≤ 4, 00: very good

Students' responses were said to be positive if they were in good and very good categories.

For the second question, students' responses were said to be effective if more than 50% of students' responses were good.

Results and Discussion

The asynchronous and synchronous learning activities

Data collection was implemented for the first time on Tuesday, October 5, 2021, according to the class schedule. Before the first meeting began, the lecturer filled out e-learning content at https://elearning.stkippgri-bkl.ac.id/. Required content, starting from the introductory session, 1st–7th sessions, 9th–15th sessions, 8th sessions, and 16th sessions. The introductory session contains 1) explanation of course descriptions, 2) course achievements, 3) introduction forum (lecturer introduction video), 4) lecture contracts, 5) libraries, 6) attendance list. So, 1th–7th sessions and 9th–15th

sessions each contain 1) greetings and explanation sessions, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, 6) links to webinar class meetings. So, the 8th sessions and 16th sessions contain 1) greetings and explanations sessions, 2) mid-test questions or final-test questions according to the specified format. The display of e-learning can be seen in Figures 1 and 2.

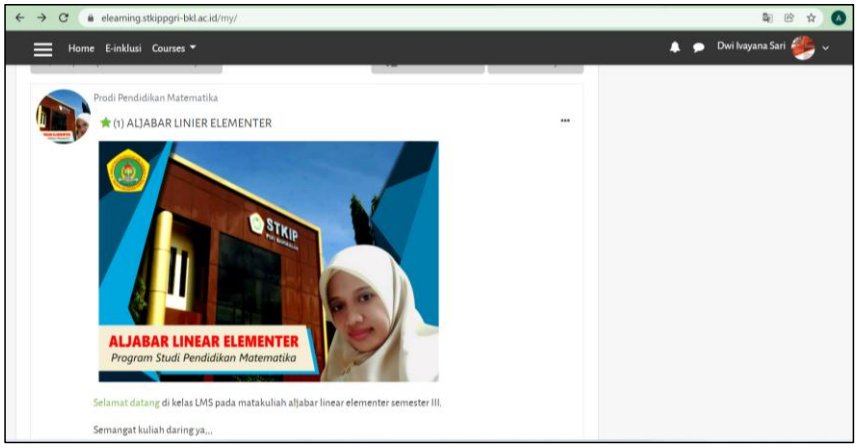

Figure 1. Front view of Elementary Linear Algebra in E-learning

Figure 2. Content Display at 1th Meeting in E-learning

The first meeting was conducted in asynchronous learning through e-learning classes. Students filled out attendance lists, accessed content in e-learning, studied teaching materials, responded to discussion forums, work assignments, and upload answers in e-learning. Synchronous learning was done through WAG. This was done if students didn't understand and needed to ask. The duration of the meeting was 10.30 - 13.00.

The second meeting was implemented in synchronous learning through a webinar class using the zoom application. Student attendance was done by filling out the attendance list in e-learning. The

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Display activity via zoom (participants and file presented) and WAG chat

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lecturer explained the material in PowerPoint and video. Students could ask and answer directly and then discussed this through this zoom application. The activity was continued with asynchronous learning in e-learning class, where students downloaded tasks in e-learning and uploaded answers in e-learning. Learning continued until the fourth, fifth, sixth, seventh meetings. Next, at the 8th meeting, students worked on mid-test questions through synchronous learning in webinar class. Previously, students downloaded questions in e-learning.

Data collection continued until the fifteenth meeting. The learning implementation on the ninth to fifteenth meetings was implemented asynchronously and synchronously like previous meetings. At the 16th meeting, students worked on final-test questions through synchronous learning in webinar class. Previously, students downloaded questions in e-learning.

The student's learning outcomes and improvement of learning outcomes

The mid-test result showed that 17 of 23 students achieved scores of more than 65% of the total score. This showed that 87% of students completed studying. This showed that there was an improvement of students' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to students' learning outcomes through just WAG. While results of the final test showed that all students achieved a score of more than 65% of the total score. This showed that 100% of students have completed studying. This showed that there was an improvement of students' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to students' learning outcomes through just WAG. Furthermore, final-test results had increased compared to mid-test results.

Based on the results of the research above, it showed that students' learning outcomes in elementary linear algebra material using asynchronous and synchronous learning approaches had increased. The results of this study were in line with the results of Zaharah, Kirilova & Windarti's (2020) research which stated that learning using E-learning brings progress and innovation to education in Indonesia because almost 75% of students conducted online learning simultaneously during the covid-19 epidemic. Sindu & Paramartha (2018) argued that theoretically, the use of instructional media based on video and slide synchronization system facilitated students at the time of learning, that is, at the time of material discussion and it made the use of instructional time more effective.

The student's responses

After all, learning was implemented, students were asked to fill out a student's response questionnaire to online learning through asynchronous and synchronous learning in elementary linear algebra material. The student's response questionnaire could be accessed by google form in link

https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN. The results of students' responses to the knowledge aspect can be seen in Figure 3.

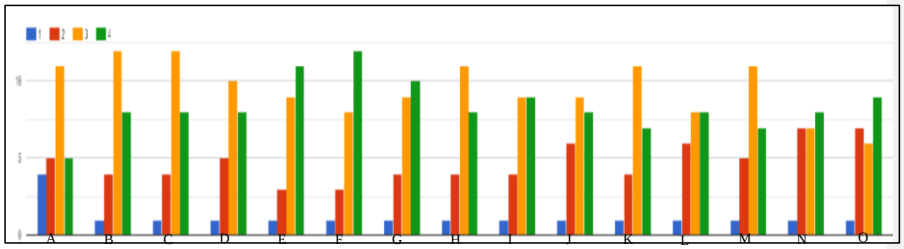

Figure 3. A. My knowledge of elementary linear algebra is very good, B. I can explain the meaning of the linear equation system, C. I can explain the Gauss Jordan elimination method, D. I can solve the system of linear equations with Gauss Jordan elimination, E. I can explain the meaning of matrix, F. I can determine operation result of two matrices, G. I can explain the meaning of determinant, H. I can determine the determinant of a matrix by using cofactor expansion, I. I can determine the determinant of a matrix by using row reduction, J. I can prove that a set is a vector space, K. I can prove that a set is a subspace of a vector space, L. I can show that some vectors are linear combinations of a vector, M. I can show that a vector spans the set, N. I can show a linearly independent set or linearly dependent, O. I can show that a set is the basis and dimension of a subspace in a vector space. Likert scale, 1=less, 2=enough, 3=good, 4=very good.

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Based on analysis results of student's responses on knowledge aspect, it showed that (1) student's knowledge of elementary linear algebra material was good category, because average student's response was 3, (2) student's ability to explain the meaning of linear equation system was good category, because average student's response was 3, (3) student's ability in explaining Gauss Jordan Elimination method was good category, because average student's response was 3, (4) student's ability to solve a system of linear equations with Gauss Jordan elimination was good category, because verage student's response was 3, (5) student's ability to explain the meaning of matrix was good category, because average student's response was 3, (6) student's ability to determine operation result of two matrices was good category, because average student's response was 3, (7) student's ability to explain the meaning of determinants was good category, because average student's response was 3, (8) student's ability to determine determinant of a matrix using cofactor expansion was good category, because average student's response was 3, (9) student's ability to determine determinant of a matrix using row reduction was good category, because average student's response was 3, (10) student's ability to prove a set was a vector space was good category, because average student's response was 3, (11) student's ability to prove that a set was a subspace of another set was good category, because average student's response was 3, (12) student's ability to show that a set was a linear combination of other sets was good category, because average student's response was 3, (13) student's ability to show that an element spans a set was good category, because average student's response was 3, (14) student's ability to show show a linearly independent set or

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linearly dependent was good category, because average student's response was 3, (15) student's ability to show that a set was basis and dimension of a subspace in a vector space were good category, because average student's response was 3. This showed that students' response to the knowledge aspect was positive.

The result of students' responses to the knowledge aspect supported the result of improving students' learning outcomes in the previous analysis. These results indicated that students had good knowledge of elementary linear algebra material after asynchronous and synchronous learning was implemented. This was because the availability of teaching materials in e-learning or e-learning classes was very helpful for students in understanding material before students discussed it in webinar classes. Therefore, mathematics learning would not experience difficulties during this pandemic if the material presentation had been presented in an e-learning class. This was under the opinion of Das (2020) who stated that mathematics education would be easier if virtual math classrooms can be presented to students through the internet. Furthermore, Noviani (2021) recommended that e-learning design was under learning objectives to minimize barriers.

The result of students' responses to attitudes aspect in online learning (synchronous and asynchronous learning) can be seen in Figure 4 below.

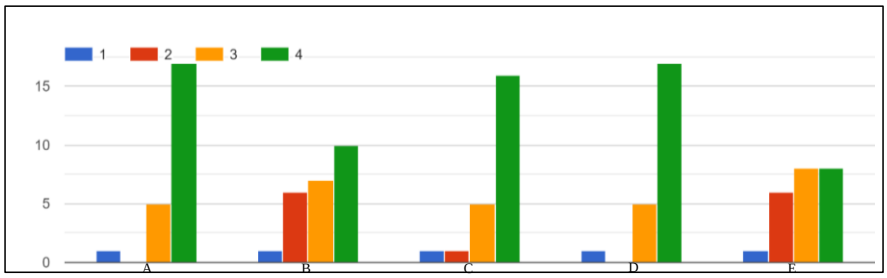

Figure 4. A. I always download teaching materials in e-learning, B. I always respond to discussion forums on e-learning, C. I always download tasks in e-learning, work tasks, and upload answers in e-learning, D. I always take webinar classes, E. I actively ask and answer during webinar class. Likert scale, 1=less, 2=enough, 3=good, 4=very good.

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Based on analysis results of student responses on attitudes aspect, it showed that (1) student's habits in downloading teaching materials in e-learning were a good category, because average student's response was 4, (2) student's habits in responding to discussion forums in e-learning were good category because average student's response was 3, (3) student's habits in downloading tasks in e-learning, work tasks and uploading answers in e-learning were good category because average student response was 4, (4) student's habits in taking webinar classes were good category because average student's response was 4, (5) student's habits to actively ask and answer during synchronous classes were good category because average student's response was 3. This showed that students' response to attitudes aspect was positive.

Students' attitude in asynchronous and synchronous learning was one of the factors of positive students' knowledge of elementary linear algebra. Students were enthusiastic about this online learning. Students were active in online learning, both asynchronous and synchronous learning. The results of this study were in line with the results of Wijaya's research (2020) which resulted in there was a good student learning attitude towards the learning video. Students felt that learning the video was very interesting yet effective as they were able to understand the concept taught.

The result of students' responses to the use of e-learning and webinar classes applications can be seen in Figure 5 and Figure 6 below.

Figure 5. The result of students' responses to the use of e-learning class applications. 23 students responded to this question

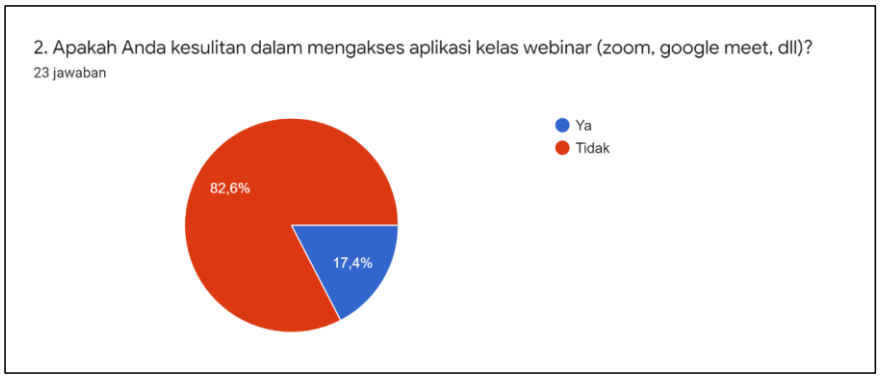

Figure 6. The result of students' responses to the use of webinar class application. 23 students responded to this question

Based on Figure 5, showed that 60.9% of students had no difficulty in using e-learning class applications. While Figure 6 showed that 82.6% of students had no difficulty in using webinar class applications. This showed that students' skills in using e-learning and webinar classes applications were effective.

The result of students' responses to the use of e-learning and webinar classes applications supported students' attitudes towards online learning through asynchronous and synchronous learning. Students had no difficulty in participating in e-learning and webinar classes. This showed that students were ready to face the industrial 4.0 period as suggested by Mairing, et. al (2021).

Furthermore, the result of students' responses to the usefulness of e-learning and webinar classes applications can be seen in Figure 7 and Figure 8 below.

Figure 7. The result of student's responses to the usefulness of e-learning class application

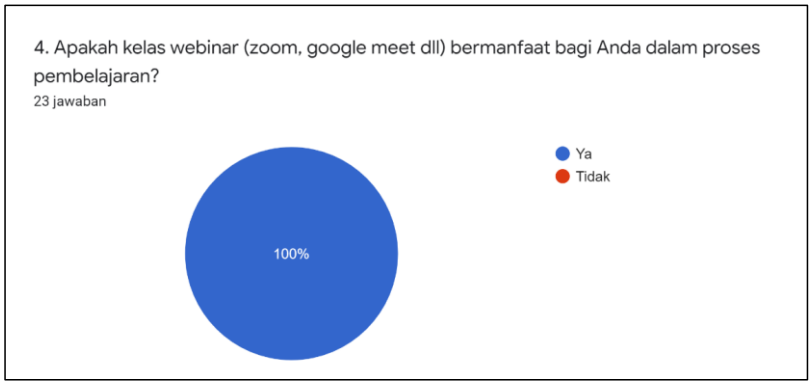

Figure 8. The result of student's responses to the usefulness of webinar class application

Based on Figures 7 and 8, showed that 100% of students responded that e-learning and webinar classes were beneficial for them. The result of students' responses to the usefulness of e-learning and webinar classes applications also supported students' attitudes towards online learning through asynchronous and synchronous learning. Students felt that e-learning and webinar classes were very useful so students were enthusiastic and active in online learning. This was in Amiti's opinion (2020) which stated that the overall study results showed that even though there could be a

preference for both e-learning methods, both synchronous and asynchronous e-learning methods if combined right, it could help teachers and learners, have a successful course and results.

Figure 9 below showed the frequency of students accessing e-learning classes in a week.

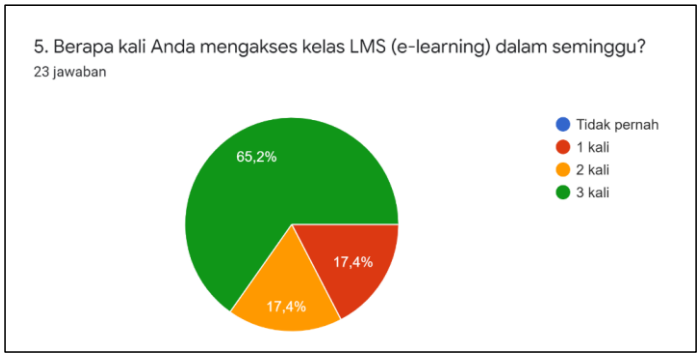

Figure 9. The result of students' responses to the frequency of accessing e-learning class in a week. There are 3 options, namely 1 time, 2 times, or 3 times in a week.

Based on Figure 9, there were 65.2% of students accessed e-learning classes 3 times a week, 17.4% of students accessed e-learning classes 1 or 2 times a week. These results indicated that students were enthusiastic and active in online learning through asynchronous and synchronous learning. More than 50% of students accessed e-learning 3 times a week. It reflected that students made good use of this e-learning facility to support their learning process. E-learning could provide everything students needed to learn. This was in line with the opinion of Xie, Liu, Bhairma, Shim (2018) who stated that students preferred to use asynchronous learning because they could easily access it offline. In addition, the asynchronous learning model was useful for shy students and was not used in virtual discussions through computers. Raymond, Atsumbe, Okwori, and Jebba (2016) recommend that higher education institutions used innovative e-learning platforms and encouraged lecturers to not only use synchronous learning in teaching but also used asynchronous learning.

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Conclusion

The results showed that the application of asynchronous learning and synchronous learning could improve students' learning outcomes in online learning. It can be seen from classical completeness studying after mid-test was higher than classical completeness studying through just WAG. This also supported by the result of classical completeness studying after the final test was higher than classical completeness studying after the mid-test.

The questionnaire results showed that most of the students gave a positive response to asynchronous and synchronous learning. Students' response to the knowledge aspect was positive, students' attitude towards learning was positive, students were able to access e-learning and

webinars classes easily, students thought that e-learning and webinar classes were very useful and helped their learning. Furthermore, students often accessed e-learning to study materials and downloaded tasks, work tasks, and upload tasks' answers in e-learning.

Further research can apply asynchronous and synchronous learning with different learning activity designs. An example of a research objective is to compare the effectiveness of other online learning with asynchronous and synchronous learning on students' learning outcomes and student responses. If the pandemic is over, then the effectiveness of blended learning by combining directly face-to-face learning with asynchronous learning (e-learning) also needs to be researched. Research's focus can be done on 4Cs (critical thinking, creativity, communication, and collaboration) because 4 abilities are very much needed in this 4.0 era.

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E-learning: Student's Perspective about Asynchronous and Synchronous Learning at Elementary Linear Algebra Material

Abstract. *Since the end of 2019, Indonesia had experienced a COVID-19 pandemic. It had changed the learning process from face-to-face to full-online. In early 2020, STKIP PGRI Bangkalan implemented online learning through WAG (WhatsApp Group), However, the learning result showed that 75% of students were not being complete in elementary linear algebra material. Online learning through Asynchronous learning by using e-learning with moodle platform was one solution to solve the problem. However, asynchronous learning needs to be combined with synchronous learning so that students can face-to-face virtual with lecturers. The purpose of this study was to determine improvement in students' learning outcomes and determine students' responses. The research design used was one group posttest-only design. 23 subjects were selected by clustered random sampling. Data were analyzed by descriptive statistical analysis. Results show that asynchronous and synchronous learning can improve students' learning outcomes. Results of the questionnaire showed that most students gave a positive response to asynchronous learning and synchronous learning.*

Keywords*: Asynchronous learning, synchronous learning, e-learning, elementary linear algebra*

Abstract. *Sejak akhir tahun 2019, Indonesia mengalami pandemic covid-19. Pandemic ini mengubah proses pembelajaran dari tatap muka menjadi fullonline. Di awal tahun 2020, STKP PGRI Bangkalan melaksanakan pembelajaran daring melalui WAG (WhatsApp Group). Namun pembelajaran ini mengakibatkan 75% mahasiswa tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui Asynchronous learning dengan memanfaatkan e-learning berupa platform moddle menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, Asynchronous learning perlu dikombinasikan dengan synchronous learning agar mahasiswa dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa dan respon mahasiswa. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa pembelajaran asynchronous dan synchronous learning dapat meningkatkan hasil belajar mahasiswa. Hasil angket menunjukkan bahwa sebagian besar mahasiswa memberikan respon positif terhadap pembelajaran asynchronous dan synchronous learning.*

Keywords*: Asynchronous learning, synchronous learning, e-learning, aljabar linear elementer*

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Introduction

At the end of 2019, Word was shaken by emerging a new coronavirus called Novel Corona Virus (2019-nCoV). This virus was originally discovered in Wuhan China in December 2019. A very significant spread to all countries in the world occurred in early 2020, including Indonesia. This was the cause of the covid-19 pandemic in Indonesia.

The covid-19 pandemic in Indonesia had a big impact in various fields, ranging from Health, Economy, and Education fields. In education fields, educational's institutions ranging from Kindergarten to Universities didn't implement face-to-face learning to reduce personal contact. Furthermore, Azhari & Fajri (2020) stated that to avoid the spread of Covid-19, the government gave the policy to close classrooms without stopping learning, so that schools implemented distance learning. Since 2020, learning had changed from face-to-face learning to online learning by using information technology (Rehman & Fatima, 2021).

In early 2020, online learning was implemented at STKP PGRI Bangkalan through WAG (WhatsApp Group). However, learning through WAG had many shortcomings, especially in an elementary linear algebra course. Based on learning outcomes data, it showed that 75% of students didn't complete studying. This means that 20% of students had completed studying. This learning outcome had decreased significantly compared to results of previous studies regarding the effectiveness of learning in an elementary linear algebra course, which showed that 86% of students had completed their studies (Sari, 2016).

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Whereas elementary linear algebra course is a basic course that must be mastered by students because elementary linear algebra course is a prerequisite course for studying further courses such as abstract algebra. This is under the opinion of Suryaningsih (2016) & Ruswana (2019) who stated that elementary linear algebra was a basic subject that must be mastered by low-level students.

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Based on the explanation above, online learning needs to be changed. It can be implemented by using asynchronous learning. Skylar (2009) stated that Asynchronous courses provide students with a flexible environment that was self-paced with students accessing course content using a variety of tools. Students were not restricted to a set day/time for communicating, and it allowed students more time to prepare a response to a set of directions or questions. Asynchronous learning is implemented by using the university's e-learning with moodle platform. According to Hambrecht in Ogbonna, Ibezim & Obi (2019) e-learning was defined as 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. E-learning contains content for one semester, are materials, discussion forums, and assignments. Yuhasriyati et.al (2020) stated that the use of e-learning may force educational processes to run faster in terms of accessibility and quality. The use of e-learning was also very influential on learning activities and students' learning outcomes (Fitriani & Nurjannah, 2019). Furthermore, Lin, Tseng & Chiang (2017) explained that students gave positive feedback on the use of Moodle learning platform for mathematics after experiencing blended learning.

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Before pandemic, e-learning can be implemented in blended learning, namely combining online learning through e-learning with face-to-face learning directly. There were several studies had shown that blended learning showed significant success in improving students' learning outcomes. As research results by Lin, Tseng & Chiang (2017) stated that ANCOVA and MANCOVA analyses showed that blended learning experience benefitted students in the experimental group by having a positive effect not only on learning outcomes but also on their attitudes toward studying mathematics in a blended environment. These results are in line with the research of Sukma & Priatna (2020) which explained that the implementation of blended learning in Mathematics had the potential to improve student's critical thinking skills (CTS).

However, during this pandemic learning was implemented fully online (Trenholm & Peschke, 2020), which means that learning was implemented using e-learning without face-to-face directly. Therefore, synchronous learning was an alternative to virtual face-to-face learning between lecturer and students. Shi & Morrow in Skylar (2009) stated that in real-time synchronous courses, the instructor leads the learning, and all learners were logged on simultaneously and communicated directly with each other.

Synchronous learning at STKIP PGRI Bangkalan was implemented by using zoom application, google meet application, etc. The aims of synchronous learning to students could understand the material so that student's learning outcomes were good. This is in line with the research results of Aisyah and Sari (2021) which stated that the use of the Google meet platform could improve students' learning outcomes.

Therefore, online learning using asynchronous learning through e-learning and synchronous learning through the virtual conference was an alternative in implementing elementary linear algebra learning. Many previous research results showed the success of asynchronous and synchronous learning. Research by Ogbonna & Ibezim (2019) showed that synchronous and asynchronous e-learning modes increased the cognitive academic achievement of students in word processing.

In the middle of 2020, STKP PGRI Bangkalan took a policy related to online learning implemented in 2 ways, namely asynchronous and synchronous learning. However, synchronous learning was implemented between 7-8 meetings. While asynchronous learning was implemented in full, namely 14-16 meetings. Asynchronous learning was implemented in e-learning classes, while synchronous learning was implemented in webinar classes (zoom, google meet, etc.).

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However, this implementation’s change of online learning needs to be evaluated for its implementation. One of them was the student’s perspective because students were objects of

learning. Student success was the output of learning application by the lecturer. Based on this explanation, the aims of this study were 1) to determine the improvement of students' learning outcomes through asynchronous and synchronous learning in elementary linear algebra material and 2) to determine students' responses to asynchronous and synchronous learning.

Method

Research Design

The author applied treatment to the participant's group, to determine the improvement of students' learning outcomes on elementary linear algebra material and students' responses to asynchronous and synchronous learning. Asynchronous learning was implemented in e-learning classes with moodle platform. Meanwhile, synchronous learning was implemented in the webinar class using zoom application.

The learning effectiveness was measured using two types, namely tests and a list of questions. Instruments were given to participants after learning implementation. The author applied to learn in one class by asynchronous and synchronous learning. Therefore, this study was an experimental study using a one-group posttest-only design.

Participants

The population in this study was all students of the mathematics education study program at STKIP PGRI Bangkalan in the odd academic year 2021/2022, totaling 34 students. The author took a sample using clustered random sampling so that there were 23 students as a sample. The sample was heterogeneous based on gender and initial mathematical ability. Initial math skills were taken from calculus scores in the previous semester.

Instruments

Research instruments were lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of sixteen meetings, eight meetings were implemented in e-learning and webinar classes, eight more meetings were implemented in e-learning classes and WhatsApp Group (WAG), and then two other meetings were implemented for tests. The author implemented 8 webinar classes because it was under campus rules that implementation of synchronous learning through webinar classes was implemented 7-8 times, this was due to constraints in purchasing internet quota. In this case, the 8th meeting (mid-test session) and the 16th meeting (final-test session) were conducted in e-learning and webinar class.

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Table 1. Activities of each meeting

Meeting	Activities	Application
1	a. Students learn about linear equations and systems and linear equations in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
2	a. Students pay attention to the lecturer's exploration about Gauss and Gauss Jordan elimination through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
3	a. Students learn about matrix and matrix operations in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
4	a. Students pay attention to the lecturer's explanation about algebra properties of the matrix through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
5	a. Students learn about elementary matrices and methods to find matrix inverse in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
6	a. Students pay attention to the lecturer's explanation about solving systems of linear equations and inverse matrix properties through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
7	a. Students learn about diagonal, symmetrical, and triangular matrices in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
8	Mid-test a. Students download mid-test questions on e-learning b. Students did mid-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)
9	a. Students learn about determine determinants by cofactor expansion and row reduction in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
10	a. Students pay attention to the lecturer's explanation about determinant properties and Crammer's rule through zoom application b. Students discuss and ask if there is a concept that is not understood	E-learning class and Webinar class (zoom)

	c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	
11	a. Students learn about vector space in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
12	a. Students pay attention to the lecturer's explanation about vector subspace through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
13	a. Students learn about linear combination and span in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
14	a. Students pay attention to the lecturer's explanation about linearly independent and linearly dependent b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students did assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
15	a. Students learn about base and dimensions in e-learning b. Students discuss through discussion forums in e-learning c. Students did assignments and upload their answers on e-learning	E-learning class and WAG
16	Final-test a. Students download final-test questions on e-learning b. Students did final-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)

The author gives mid-test and final-test at the 8th and 16th meetings. Test questions were developed according to the material in the lesson plan.

Table 2. 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 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 not both.	√			C2	Matrix	3	10
4	Given the system of linear	√			C3	Gauss Jordan	4	15

	equations, students can solve the system of linear equations using Gauss Jordan elimination			Elimination		
5	Given the system of linear equations, students can determine the coefficient value of one linear equation so that the system of linear equations, 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 inverse matrix by the inverse algorithm	√	C2	Inverse matrix	7	15
8	Given several matrices, students can determine upper triangular matrix, lower triangular matrix, and diagonal matrix	√	C2	Matrix	8	10

Tabel 3. 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 matrix determinant by using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system of linear equations 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 can determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that three 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 basis S of $M_{2,2}$ and students can determine dimensions of the S subspace of $M_{2,2}$	√			C3	Basis and dimension	8	10

The author developed a questionnaire to measure students' responses to the approach. The statements on the questionnaire used a Likert scale. Aspects of the questionnaire and indicators can be seen in Table 4.

Table 4. Aspects and Indicators of The Questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	Student's knowledge of elementary linear algebra material through online learning
			Student's ability to understand every elementary linear algebra material through online learning
			Student's ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in Asynchronous and synchronous learning	Student's response when independently learning through learning resources in e-learning
			Student's responses when responding to discussion forums
			Student's responses when downloading assignments in e-learning, work it and upload answers in e-learning
			Student's responses about taking synchronous learning
			Student responses when discussing through webinar classes
			Frequency of students accessing e-learning
3.	E-learning dan Webinar classes applications	Ease of access and usefulness for students	Ease of accessing e-learning class application
			Ease of accessing webinar class application
			The usefulness of accessing e-learning class application
			The usefulness of accessing e-learning class application

The Procedure of Data Collection

Data collection was done by giving tests and questionnaires. The instrument was given online by using e-learning and google form. Learning implementation by using asynchronous and synchronous learning in line with lesson plan design.

Data Analysis

Data analysis in this study used descriptive statistical analysis because the aim was to explain and provide an overview of characteristics of a series of data, without doing any generation. After the test result data and student's response data were collected, authors analyzed data as follows:

1. Analysis of test result data

   Data analysis of test results was measured using a completeness test. This completeness test consists of an individual completeness test and a classical completeness test. The Ministry of Education and Culture categorizes students' scores into 5 categories 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

Furthermore, Widoyoko (2009) determines 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

Based on the criteria above, the author established criteria for individual completeness, namely that students were said to have completed learning if they got a score of 65% of the total score. While classical completeness criteria were 80% of students have completed their studies. Improved learning outcomes were achieved if students' learning outcomes after mid-test were higher than students' learning outcomes before being given treatment. Then students' learning outcomes of the final-test were higher than students' learning outcomes of the mid-test.

2. Analysis of student's response data

Student's response data obtained from questionnaires consists of 2 types. This was because questions from the questionnaire consist of 2 kinds, namely questions with 4 answers (1,2,3,4) and questions with 2 answers (yes and no).

For the first question, the criteria were 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

Students' responses were said to be positive if they were in good and very good categories.

For the second question, students' responses were said to be effective if more than 50% of students' responses were good.

Results and Discussion

The asynchronous and synchronous learning activities

Data collection was implemented for the first time on Tuesday, October 5, 2021, according to the class schedule. Before the first meeting began, the lecturer filled out e-learning content at https://elearning.stkippgri-bkl.ac.id/. Required content, starting from the introductory session, 1st–7th sessions, 9th–15th sessions, 8th sessions, and 16th sessions. The introductory session contains 1) explanation of course descriptions, 2) course achievements, 3) introduction forum (lecturer introduction video), 4) lecture contracts, 5) libraries, 6) attendance list. So, 1th–7th sessions and 9th–15th

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sessions each contain 1) greetings and explanation sessions, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, 6) links to webinar class meetings. So, the 8th sessions and 16th sessions contain 1) greetings and explanations sessions, 2) mid-test questions or final-test questions according to the specified format. The display of e-learning can be seen in Figures 1 and 2.

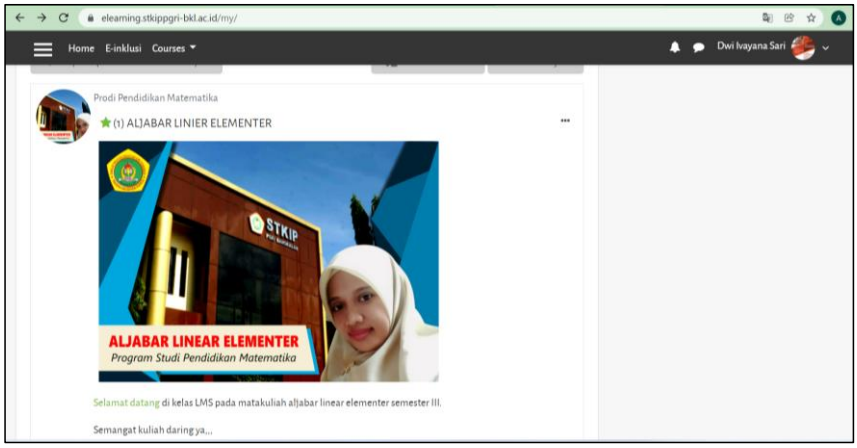

Figure 1. Front view of Elementary Linear Algebra in E-learning

Figure 2. Content Display at 1th Meeting in E-learning

The first meeting was conducted in asynchronous learning through e-learning classes. Students filled out attendance lists, accessed content in e-learning, studied teaching materials, responded to discussion forums, work assignments, and upload answers in e-learning. Synchronous learning was done through WAG. This was done if students didn't understand and needed to ask. The duration of the meeting was 10.30 - 13.00.

The second meeting was implemented in synchronous learning through a webinar class using the zoom application. Student attendance was done by filling out the attendance list in e-learning. The

lecturer explained the material in PowerPoint and video. Students could ask and answer directly and then discussed this through this zoom application. The activity was continued with asynchronous learning in e-learning class, where students downloaded tasks in e-learning and uploaded answers in e-learning. Learning continued until the fourth, fifth, sixth, seventh meetings. Next, at the 8th meeting, students worked on mid-test questions through synchronous learning in webinar class. Previously, students downloaded questions in e-learning.

Data collection continued until the fifteenth meeting. The learning implementation on the ninth to fifteenth meetings was implemented asynchronously and synchronously like previous meetings. At the 16th meeting, students worked on final-test questions through synchronous learning in webinar class. Previously, students downloaded questions in e-learning.

The student's learning outcomes and improvement of learning outcomes

The mid-test result showed that 17 of 23 students achieved scores of more than 65% of the total score. This showed that 87% of students completed studying. This showed that there was an improvement of students' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to students' learning outcomes through just WAG. While results of the final test showed that all students achieved a score of more than 65% of the total score. This showed that 100% of students have completed studying. This showed that there was an improvement of students' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to students' learning outcomes through just WAG. Furthermore, final-test results had increased compared to mid-test results.

Based on the results of the research above, it showed that students' learning outcomes in elementary linear algebra material using asynchronous and synchronous learning approaches had increased. The results of this study were in line with the results of Zaharah, Kirilova & Windarti's (2020) research which stated that learning using E-learning brings progress and innovation to education in Indonesia because almost 75% of students conducted online learning simultaneously during the covid-19 epidemic. Sindu & Paramartha (2018) argued that theoretically, the use of instructional media based on video and slide synchronization system facilitated students at the time of learning, that is, at the time of material discussion and it made the use of instructional time more effective.

The student's responses

After all, learning was implemented, students were asked to fill out a student's response questionnaire to online learning through asynchronous and synchronous learning in elementary linear algebra material. The student's response questionnaire could be accessed by google form in link

https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN. The results of students' responses to the knowledge aspect can be seen in Figure 3.

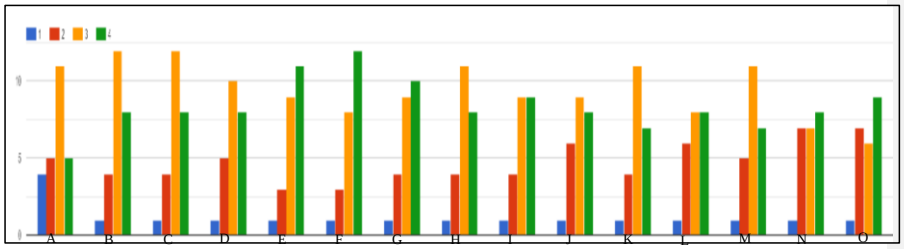

Figure 3. A. My knowledge of elementary linear algebra is very good, B. I can explain the meaning of the linear equation system, C. I can explain the Gauss Jordan elimination method, D. I can solve the system of linear equations with Gauss Jordan elimination, E. I can explain the meaning of matrix, F. I can determine operation result of two matrices, G. I can explain the meaning of determinant, H. I can determine the determinant of a matrix by using cofactor expansion, I. I can determine the determinant of a matrix by using row reduction, J. I can prove that a set is a vector space, K. I can prove that a set is a subspace of a vector space, L. I can show that some vectors are linear combinations of a vector, M. I can show that a vector spans the set, N. I can show a linearly independent set or linearly dependent, O. I can show that a set is the basis and dimension of a subspace in a vector space. Likert scale, 1=less, 2=enough, 3=good, 4=very good.

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Based on analysis results of student's responses on knowledge aspect, it showed that (1) student's knowledge of elementary linear algebra material was good category, because average student's response was 3, (2) student's ability to explain the meaning of linear equation system was good category, because average student's response was 3, (3) student's ability in explaining Gauss Jordan Elimination method was good category, because average student's response was 3, (4) student's ability to solve a system of linear equations with Gauss Jordan elimination was good category, because verage student's response was 3, (5) student's ability to explain the meaning of matrix was good category, because average student's response was 3, (6) student's ability to determine operation result of two matrices was good category, because average student's response was 3, (7) student's ability to explain the meaning of determinants was good category, because average student's response was 3, (8) student's ability to determine determinant of a matrix using cofactor expansion was good category, because average student's response was 3, (9) student's ability to determine determinant of a matrix using row reduction was good category, because average student's response was 3, (10) student's ability to prove a set was a vector space was good category, because average student's response was 3, (11) student's ability to prove that a set was a subspace of another set was good category, because average student's response was 3, (12) student's ability to show that a set was a linear combination of other sets was good category, because average student's response was 3, (13) student's ability to show that an element spans a set was good category, because average student's response was 3, (14) student's ability to show show a linearly independent set or

linearly dependent was good category, because average student's response was 3, (15) student's ability to show that a set was basis and dimension of a subspace in a vector space were good category, because average student's response was 3. This showed that students' response to the knowledge aspect was positive.

The result of students' responses to the knowledge aspect supported the result of improving students' learning outcomes in the previous analysis. These results indicated that students had good knowledge of elementary linear algebra material after asynchronous and synchronous learning was implemented. This was because the availability of teaching materials in e-learning or e-learning classes was very helpful for students in understanding material before students discussed it in webinar classes. Therefore, mathematics learning would not experience difficulties during this pandemic if the material presentation had been presented in an e-learning class. This was under the opinion of Das (2020) who stated that mathematics education would be easier if virtual math classrooms can be presented to students through the internet. Furthermore, Noviani (2021) recommended that e-learning design was under learning objectives to minimize barriers.

The result of students' responses to attitudes aspect in online learning (synchronous and asynchronous learning) can be seen in Figure 4 below.

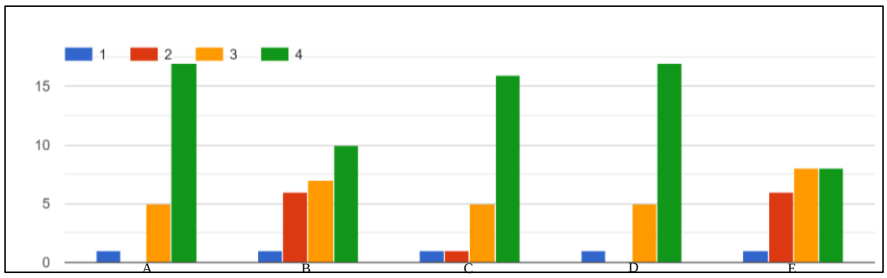

Figure 4. A. I always download teaching materials in e-learning, B. I always respond to discussion forums on e-learning, C. I always download tasks in e-learning, work tasks, and upload answers in e-learning, D. I always take webinar classes, E. I actively ask and answer during webinar class. Likert scale, 1=less, 2=enough, 3=good, 4=very good.

Based on analysis results of student responses on attitudes aspect, it showed that (1) student's habits in downloading teaching materials in e-learning were a good category, because average student's response was 4, (2) student's habits in responding to discussion forums in e-learning were good category because average student's response was 3, (3) student's habits in downloading tasks in e-learning, work tasks and uploading answers in e-learning were good category because average student response was 4, (4) student's habits in taking webinar classes were good category because average student's response was 4, (5) student's habits to actively ask and answer during synchronous classes were good category because average student's response was 3. This showed that students' response to attitudes aspect was positive.

Students' attitude in asynchronous and synchronous learning was one of the factors of positive students' knowledge of elementary linear algebra. Students were enthusiastic about this online learning. Students were active in online learning, both asynchronous and synchronous learning. The results of this study were in line with the results of Wijaya's research (2020) which resulted in there was a good student learning attitude towards the learning video. Students felt that learning the video was very interesting yet effective as they were able to understand the concept taught.

The result of students' responses to the use of e-learning and webinar classes applications can be seen in Figure 5 and Figure 6 below.

Figure 5. The result of students' responses to the use of e-learning class applications. 23 students responded to this question

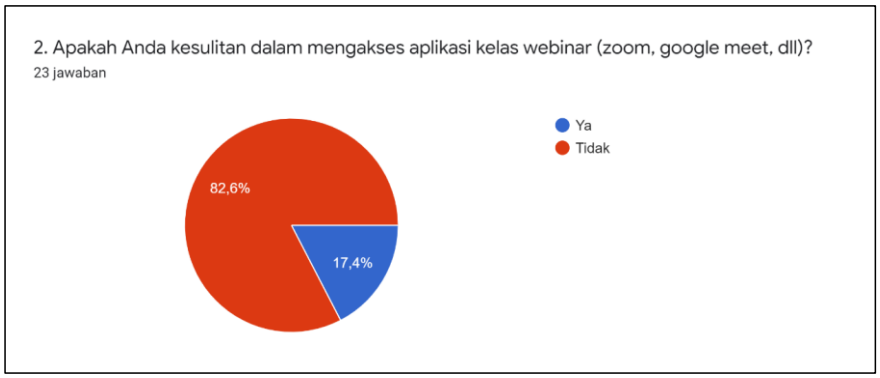

Figure 6. The result of students' responses to the use of webinar class application. 23 students responded to this question

Based on Figure 5, showed that 60.9% of students had no difficulty in using e-learning class applications. While Figure 6 showed that 82.6% of students had no difficulty in using webinar class applications. This showed that students' skills in using e-learning and webinar classes applications were effective.

The result of students' responses to the use of e-learning and webinar classes applications supported students' attitudes towards online learning through asynchronous and synchronous learning. Students had no difficulty in participating in e-learning and webinar classes. This showed that students were ready to face the industrial 4.0 period as suggested by Mairing, et. al (2021).

Furthermore, the result of students' responses to the usefulness of e-learning and webinar classes applications can be seen in Figure 7 and Figure 8 below.

Figure 7. The result of student's responses to the usefulness of e-learning class application

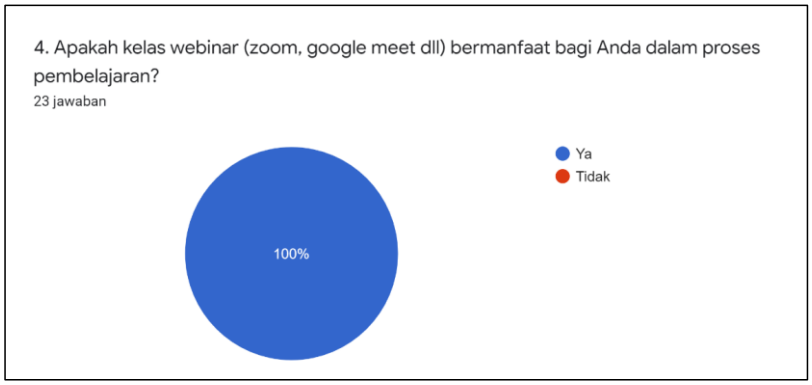

Figure 8. The result of student's responses to the usefulness of webinar class application

Based on Figures 7 and 8, showed that 100% of students responded that e-learning and webinar classes were beneficial for them. The result of students' responses to the usefulness of e-learning and webinar classes applications also supported students' attitudes towards online learning through asynchronous and synchronous learning. Students felt that e-learning and webinar classes were very useful so students were enthusiastic and active in online learning. This was in Amiti's opinion (2020) which stated that the overall study results showed that even though there could be a

preference for both e-learning methods, both synchronous and asynchronous e-learning methods if combined right, it could help teachers and learners, have a successful course and results.

Figure 9 below showed the frequency of students accessing e-learning classes in a week.

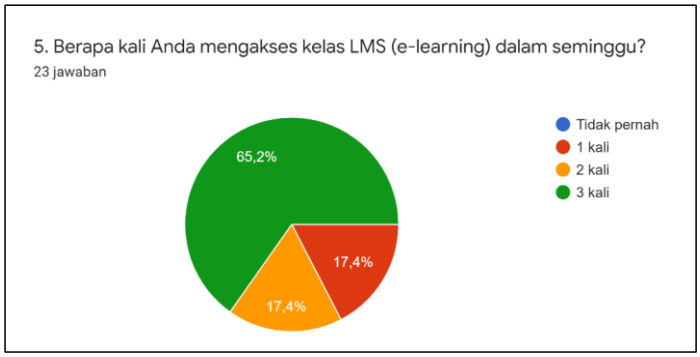

Figure 9. The result of students' responses to the frequency of accessing e-learning class in a week. There are 3 options, namely 1 time, 2 times, or 3 times in a week.

Based on Figure 9, there were 65.2% of students accessed e-learning classes 3 times a week, 17.4% of students accessed e-learning classes 1 or 2 times a week. These results indicated that students were enthusiastic and active in online learning through asynchronous and synchronous learning. More than 50% of students accessed e-learning 3 times a week. It reflected that students made good use of this e-learning facility to support their learning process. E-learning could provide everything students needed to learn. This was in line with the opinion of Xie, Liu, Bhairma, Shim (2018) who stated that students preferred to use asynchronous learning because they could easily access it offline. In addition, the asynchronous learning model was useful for shy students and was not used in virtual discussions through computers. Raymond, Atsumbe, Okwori, and Jebba (2016) recommend that higher education institutions used innovative e-learning platforms and encouraged lecturers to not only use synchronous learning in teaching but also used asynchronous learning.

Conclusion

The results showed that the application of asynchronous learning and synchronous learning could improve students' learning outcomes in online learning. It can be seen from classical completeness studying after mid-test was higher than classical completeness studying through just WAG. This also supported by the result of classical completeness studying after the final test was higher than classical completeness studying after the mid-test.

The questionnaire results showed that most of the students gave a positive response to asynchronous and synchronous learning. Students' response to the knowledge aspect was positive, students' attitude towards learning was positive, students were able to access e-learning and

webinars classes easily, students thought that e-learning and webinar classes were very useful and helped their learning. Furthermore, students often accessed e-learning to study materials and downloaded tasks, work tasks, and upload tasks' answers in e-learning.

Further research can apply asynchronous and synchronous learning with different learning activity designs. An example of a research objective is to compare the effectiveness of other online learning with asynchronous and synchronous learning on students' learning outcomes and student responses. If the pandemic is over, then the effectiveness of blended learning by combining directly face-to-face learning with asynchronous learning (e-learning) also needs to be researched. Research's focus can be done on 4Cs (critical thinking, creativity, communication, and collaboration) because 4 abilities are very much needed in this 4.0 era.

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HASIL REVISI BERDASARKAN REVIEW TAHAP 1 DARI REVIEWER 1 DAN 2

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Synchronous and Asynchronous Learning through E-Learning for Preservice Teachers on Elementary Linear Algebra Material

Abstract. *The learning process changed from face-to-face to full-online, since Indonesia had experienced a COVID-19 pandemic in the end of 2019. In early 2020, one of teacher education program in Bangkalan, Indonesia implemented online learning through WhatsApp Group (WAG). However, the learning result showed that 75% of preservice teacher were not being complete in elementary linear algebra material. Online learning through asynchronous learning by using e-learning with moodle platform was one solution to solve the problem. However, asynchronous learning needs to be combined with synchronous learning so that preservice teacher can face-to-face virtually with lecturers. The purpose of this study was to determine improvement in preservice teachers' learning outcomes and preservice teachers' responses to asynchronous and synchronous learning. The research design used was one group posttest-only design. 23 subjects were selected by clustered random sampling. Data were analyzed by descriptive statistical analysis. Results show that asynchronous and synchronous learning can improve preservice teachers' learning outcomes. Results of the questionnaire showed that most preservice teachers gave a positive response to asynchronous learning and synchronous learning. Lecturers in teacher education program can apply online learning by synchronous and asynchronous learning through e-learning, because it affects Pedagogical Content Knowledge (PCK) of preservice teacher. Preservice teachers have experience about online learning that combines synchronous and asynchronous learning through e-learning. This can provide knowledge for preservice teachers in developing online learning methods.*

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

Abstract. *Proses pembelajaran berubah dari tatap muka menjadi fullonline, sejak Indonesia mengalami pandemic covid-19 di akhir tahun 2019. Di awal tahun 2020, salah satu perguruan tinggi keguruan di Bangkalan, Indonesia melaksanakan pembelajaran daring melalui WhatsApp Group (WAG). Namun pembelajaran ini mengakibatkan 75% mahasiswa calon guru tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui asynchronous learning dengan memanfaatkan e-learning berupa platform moddle menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, asynchronous learning perlu dikombinasikan dengan synchronous learning agar mahasiswa calon guru dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa calon guru dan respon mahasiswa calon guru terhadap asynchronous and synchronous learning. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa calon guru yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa asynchronous dan synchronous learning dapat meningkatkan hasil belajar mahasiswa calon guru. Hasil angket menunjukkan bahwa sebagian besar mahasiswa calon guru memberikan respon positif terhadap pembelajaran asynchronous dan synchronous learning. Dosen di perguruan tinggi keguruan dapat menerapkan pembelajaran daring dengan synchronous dan asynchronous lening melalui e-learning, karena ini berpengaruh pada Pedagogical Content Knowledge (PCK) mahasiswa calon guru. Mahasiswa calon guru memiliki pengalaman mengenai pembelajaran online yang mengkombinasikan synchronous and asynchronous learning melalui e-learning. Hal ini dapat memberikan pengetahuan bagi mahasiswa calon guru dalam mengembangkan metode pembelajaran daring.*

Keywords*: Asynchronous learning, synchronous learning, e-learning, mahasiswa calon guru, aljabar linear elementer*

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Introduction

At the end of 2019, Word was shaken by emerging a new coronavirus called Novel Corona Virus (2019-nCoV). This virus was originally discovered in Wuhan China in December 2019. A very significant spread to all countries in the world occurred in early 2020, including Indonesia. This was the cause of the covid-19 pandemic in Indonesia.

The covid-19 pandemic in Indonesia had a big impact in various fields, ranging from Health, Economy, and Education fields. In education fields, educational's institutions ranging from Kindergarten to Universities didn't implement face-to-face learning to reduce personal contact. Furthermore, Azhari & Fajri (2020) stated that to avoid the spread of Covid-19, the government gave the policy to close classrooms without stopping learning, so that schools implemented distance learning. Since 2020, learning had changed from face-to-face learning to online learning by using information technology (Rehman & Fatima, 2021).

In early 2020, online learning was implemented at STKIP PGRI Bangkalan through WhatsApp Group (WAG). However, learning through WAG had many shortcomings, especially in an elementary linear algebra course. Based on learning outcomes data, it showed that 75% of preservice teacher didn't complete studying. This means that 20% of preservice teacher had completed studying. This learning outcome had decreased significantly compared to results of previous studies regarding the effectiveness of learning in an elementary linear algebra course, which showed that 86% of students had completed their studies (Sari, 2016).

Whereas elementary linear algebra course is a basic course that must be mastered by students because elementary linear algebra course is a prerequisite course for studying further courses such as abstract algebra. This is under the opinion of Suryaningsih (2016) & Ruswana (2019) who stated that elementary linear algebra was a basic subject that must be mastered by low-level students. If students can master material of elementary linear algebra, then students can easily learn other subjects.

Based on the explanation above, online learning needs to be changed. It can be implemented by using asynchronous learning. Skylar (2009) stated that Asynchronous courses provide students with a flexible environment that was self-paced with students accessing course content using a variety of tools. Students were not restricted to a set day/time for communicating, and it allowed students more time to prepare a response to a set of directions or questions. Asynchronous learning is implemented by using the university's e-learning with moodle platform. According to Hambrecht (in Ogbonna, Ibezim & Obi, 2019) e-learning was defined as 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. E-learning contains content for one semester are materials,

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discussion forums, and assignments. Yuhasriyati et.al (2020) stated that the use of e-learning may force educational processes to run faster in terms of accessibility and quality. The use of e-learning was also very influential on learning activities and students' learning outcomes (Fitriani & Nurjannah, 2019). Furthermore, Lin, Tseng & Chiang (2017) explained that students gave positive feedback on the use of Moodle learning platform for mathematics after experiencing blended learning.

Before pandemic, e-learning can be implemented in blended learning, namely combining online learning through e-learning with face-to-face learning directly. There were several studies had shown that blended learning showed significant success in improving students' learning outcomes. As research results by Lin, Tseng & Chiang (2017) stated that ANCOVA and MANCOVA analyses showed that blended learning experience benefitted students in the experimental group by having a positive effect not only on learning outcomes but also on their attitudes toward studying mathematics in a blended environment. These results are in line with the research of Sukma & Priatna (2020) which explained that the implementation of blended learning in Mathematics had the potential to improve student's critical thinking skills (CTS).

However, during this pandemic learning was implemented fully online (Trenholm & Peschke, 2020), which means that learning was implemented using e-learning without face-to-face directly. Therefore, synchronous learning was an alternative to virtual face-to-face learning between lecturer and students. Shi & Morrow in Skylar (2009) stated that in real-time synchronous courses, the instructor leads the learning, and all learners were logged on simultaneously and communicated directly with each other.

Synchronous learning at STKIP PGRI Bangkalan was implemented by using zoom application, google meet application, etc. The aims of synchronous learning to students could understand the material so that student's learning outcomes were good. This is in line with the research results of Aisyah and Sari (2021) which stated that the use of the Google meet platform could improve students' learning outcomes.

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Therefore, online learning using asynchronous learning through e-learning and synchronous learning through the virtual conference was an alternative in implementing elementary linear algebra learning. Many previous research results showed the success of asynchronous and synchronous learning. Research by Ogbonna & Ibezim (2019) showed that synchronous and asynchronous e-learning modes increased the cognitive academic achievement of students in word processing.

In the middle of 2020, STKIP PGRI Bangkalan took a policy related to online learning implemented in 2 ways, namely asynchronous and synchronous learning. However, synchronous learning was implemented between 7-8 meetings. While asynchronous learning was implemented

in full, namely 14-16 meetings. Asynchronous learning was implemented in e-learning classes, while synchronous learning was implemented in webinar classes (zoom, google meet, etc.).

However, this implementation's change of online learning needs to be evaluated for its implementation. One of them was the preservice teacher's perspective because they were objects of learning. Their success was the output of learning application by the lecturer. And then, they must have pedagogic and content knowledge to become professional teachers. From pedagogic knowledge aspect, they must understand types of learning methods and from content knowledge aspect, they must master mathematical material, especially basic material, such elementary linear algebra. Based on this explanation, the aims of this study were 1) to determine the improvement of preservice teachers' learning outcomes through asynchronous and synchronous learning in elementary linear algebra material and 2) to determine preservice teachers' responses to asynchronous and synchronous learning.

Method

Research Design

The author applied treatment to the participant's group, to determine the improvement of preservice teachers' learning outcomes on elementary linear algebra material and preservice teachers' responses to asynchronous and synchronous learning. Asynchronous learning was implemented in e-learning classes with moodle platform. Meanwhile, synchronous learning was implemented in the webinar class using zoom application.

The learning effectiveness was measured using two types, namely tests and a list of questions. Instruments were given to participants after learning implementation. The author applied to learn in one class by asynchronous and synchronous learning. Therefore, this study was an experimental study using a one-group posttest-only design.

Participants

The population in this study was all preservice teachers of the mathematics education study program at STKIP PGRI Bangkalan in the odd academic year 2021/2022, totaling 34 preservice teachers. The author took a sample using clustered random sampling so that there were 23 preservice teachers as a sample. The sample was heterogeneous based on gender and initial mathematical ability. Initial math skills were taken from calculus scores in the previous semester.

Instruments

Research instruments were lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of sixteen meetings, eight meetings were implemented in e-learning and webinar classes, eight more meetings were implemented in e-learning classes and WhatsApp Group (WAG), and then two other meetings were implemented

for tests. The author implemented 8 webinar classes because it was under campus rules that implementation of synchronous learning through webinar classes was implemented 7-8 times, this was due to constraints in purchasing internet quota. In this case, the 8th meeting (mid-test session) and the 16th meeting (final-test session) were conducted in e-learning and webinar class.

Table 1. Activities of each meeting

Meeting	Activities	Application
1	a. Students learn about linear equations and systems and linear equations in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
2	a. Students pay attention to the lecturer's exploration about Gauss and Gauss Jordan elimination through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
3	a. Students learn about matrix and matrix operations in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
4	a. Students pay attention to the lecturer's explanation about algebra properties of the matrix through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
5	a. Students learn about elementary matrices and methods to find matrix inverse in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
6	a. Students pay attention to the lecturer's explanation about solving systems of linear equations and inverse matrix properties through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
7	a. Students learn about diagonal, symmetrical, and triangular matrices in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
8	Mid-test a. Students download mid-test questions on e-learning b. Students do mid-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)
9	a. Students learn about determine determinants by cofactor expansion and row reduction in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
10	a. Students pay attention to the lecturer's explanation about determinant properties and Crammer's rule through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
11	a. Students learn about vector space in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
12	a. Students pay attention to the lecturer's explanation about vector subspace through zoom application b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
13	a. Students learn about linear combination and span in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG

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14	a. Students pay attention to the lecturer's explanation about linearly independent and linearly dependent b. Students discuss and ask if there is a concept that is not understood c. Students discuss through discussion forums in e-learning d. Students do assignments and upload their answers on e-learning	E-learning class and Webinar class (zoom)
15	a. Students learn about base and dimensions in e-learning b. Students discuss through discussion forums in e-learning c. Students do assignments and upload their answers on e-learning	E-learning class and WAG
16	Final-test a. Students download final-test questions on e-learning b. Students do final-test and upload their answers on e-learning	E-learning class and Webinar class (zoom)

The author gave mid-test and final-test at the 8th and 16th meetings. Test questions were developed according to the material in the lesson plan. To get a valid mid-test and final-test, used 3 validities, namely construct validity, content validity, and face validity. Construct validity was done by ensuring that results of mid-test and final-test actually measure preservice teachers' abilities in elementary linear algebra and not other variables. Content validity was done by reviewing and making mid-test and final-test grids. Grids covered questions and prepared question indicators so that no indicators were missed. The mid-test and final-test grids can be seen in Table 2 and Table 3. Face validity was done by 2 (two) experts. Experts evaluated elements of concept truth, rules for writing questions, displays for example writing symbols and mathematical formulas, punctuation marks, pictures and language. The face validation average result for mid-test was 4.17. The face validation average result for final-test was 4.33. It means that mid-test and final-test were valid to be used.

Table 2. 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 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 not both.	√			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 so that the system of linear equations, 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 inverse matrix by the inverse algorithm	√			C2	Inverse matrix	7	15
8	Given several matrices, students can determine upper triangular matrix, lower triangular matrix, and diagonal matrix	√			C2	Matrix	8	10

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Tabel 3. 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 matrix determinant by using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system of linear equations 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 can determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that three 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 basis S of $M_{2,2}$ and students can determine dimensions of the S subspace of $M_{2,2}$	√			C3	Basis and dimension	8	10

The author developed a questionnaire to measure preservice teachers' responses to the approach. To get a valid questionnaire, used 3 validities, namely construct validity, content validity, and face validity. Construct validity was done by ensuring that results of questionnaire actually measure preservice teachers' responses to synchronous and asynchronous learning. Content validity was done by reviewing and making questionnaire grids. Grids covered questions and prepared question indicators so that no indicators were missed. Aspects of the questionnaire and indicators can be seen in Table 4. Face validity was done by 2 (two) experts. Experts evaluated elements of concept truth, rules for writing questions, displays for language. The face validation average result for questionnaire was 4.83. The statements on the questionnaire used a Likert scale.

Table 4. Aspects and Indicators of The Questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	Student's knowledge of elementary linear algebra material through online learning
			Student's ability to understand every elementary linear algebra material through online learning
			Student's ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in Asynchronous and synchronous learning	Student's response when independently learning through learning resources in e-learning
			Student's responses when responding to discussion forums
			Student's responses when downloading assignments in e-learning, work it and upload answers in e-learning
			Student's responses about taking synchronous learning
			Student responses when discussing through webinar classes
			Frequency of students accessing e-learning
3.			Ease of accessing e-learning class application

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	E-learning dan Webinar classes applications	Ease of access and usefulness for students	Ease of accessing webinar class application
			The usefulness of accessing e-learning class application
			The usefulness of accessing e-learning class application

The Procedure of Data Collection

Data collection was done by giving tests and questionnaire. The instrument was given online by using e-learning and google form. Learning implementation by using asynchronous and synchronous learning in line with lesson plan design.

Data Analysis

Data analysis in this study used descriptive statistical analysis because the aim was to explain and provide an overview of characteristics of a series of data, without doing any generation. After the test result data and preservice teacher's response data were collected, authors analyzed data as follows:

1. Analysis of test result data

   Data analysis of test results was measured using a completeness test. This completeness test consists of an individual completeness test and a classical completeness test. The Ministry of Education and Culture categorizes subjects' scores into 5 categories 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

   Furthermore, Widoyoko (2009) determines 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

   Based on the criteria above, the author established criteria for individual completeness, namely that preservice teachers were said to have completed learning if they got a score of 65% of the total score. While classical completeness criteria were 80% of preservice teachers have completed their studies. Improved learning outcomes were achieved if preservice teachers' learning outcomes after mid-test were higher than preservice teachers' learning outcomes before being given treatment. Then preservice teachers' learning outcomes of the final-test were higher than preservice teachers' learning outcomes of the mid-test.

2. Analysis of preservice teacher's response data

   Preservice teacher's response data obtained from questionnaires consists of 2 types. This was because questions from the questionnaire consist of 2 kinds, namely questions with 4 answers (1,2,3,4) and questions with 2 answers (yes and no).

For the first question, the criteria were as follows:

1, 00 ≤ average < 1, 50: less
1, 50 ≤ average < 2, 50: enough
2, 50 ≤ average < 3, 50: good
3, 50 ≤ average ≤ 4, 00: very good

Preservice teachers ' responses were said to be positive if they were in good and very good categories.

For the second question, preservice teachers' responses were said to be effective if more than 50% of students' responses were good.

Results and Discussion

The asynchronous and synchronous learning activities

Data collection was implemented for the first time on Tuesday, October 5, 2021, according to the class schedule. Before the first meeting began, the lecturer filled out e-learning content. Required content, starting from the introductory session, 1st–7th sessions, 9th–15th sessions, 8th sessions, and 16th sessions. The introductory session contains 1) explanation of course descriptions, 2) course achievements, 3) introduction forum (lecturer introduction video), 4) lecture contracts, 5) libraries, 6) attendance list. So, 1th–7th sessions and 9th–15th sessions each contain 1) greetings and explanation sessions, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, 6) links to webinar class meetings. So, the 8th sessions and 16th sessions contain 1) greetings and explanations sessions, 2) mid-test questions or final-test questions according to the specified format. The display of e-learning can be seen in Figures 1, 2 and 3, discussion and closing sessions can be seen in Figure 4 and 5, discussion sessions in WAG can be seen in Figure 6.

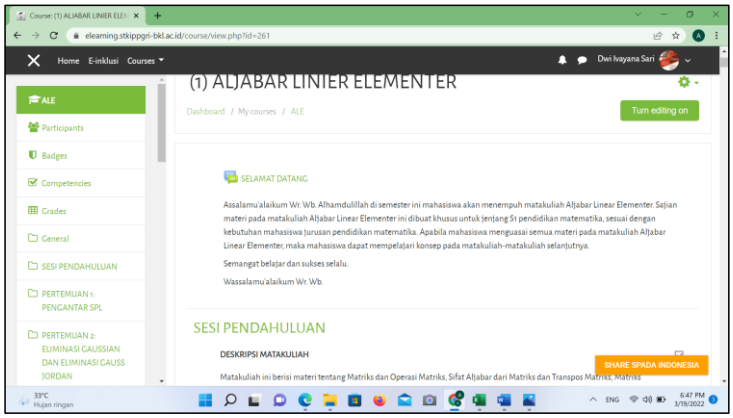

Figure 1. Front View of Elementary Linear Algebra in E-learning

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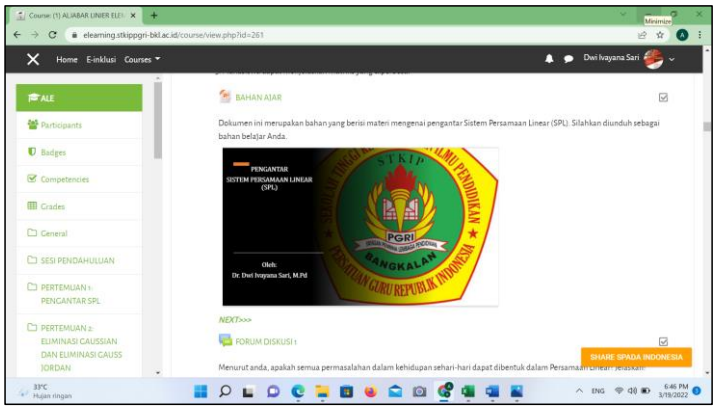

Figure 2. Content Display at 1th Meeting in E-learning

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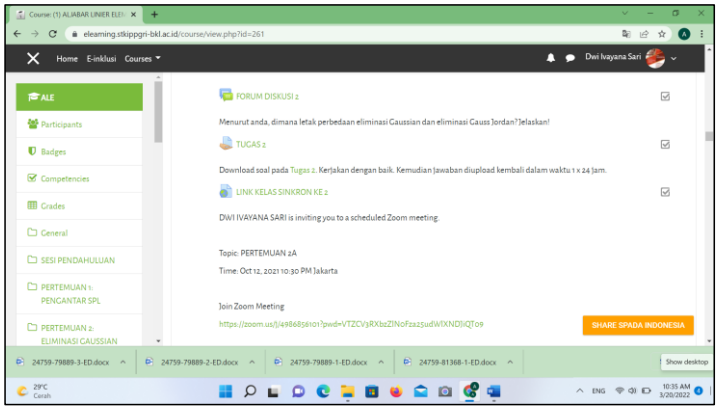

Figure 3. Content Display at 2th Meeting in E-learning

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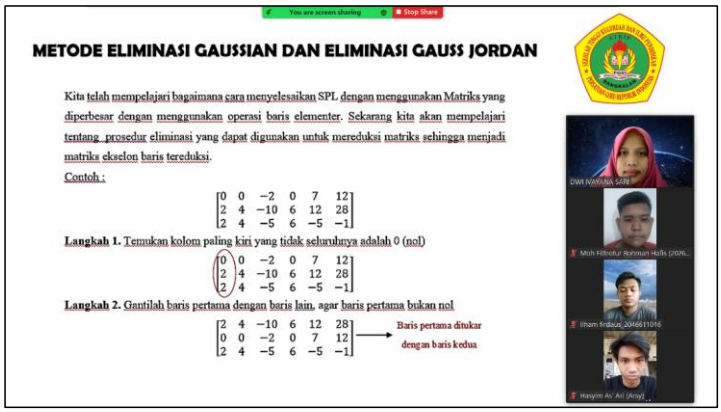

Figure 4. Discussion Session in The Webinar Class (Zoom)

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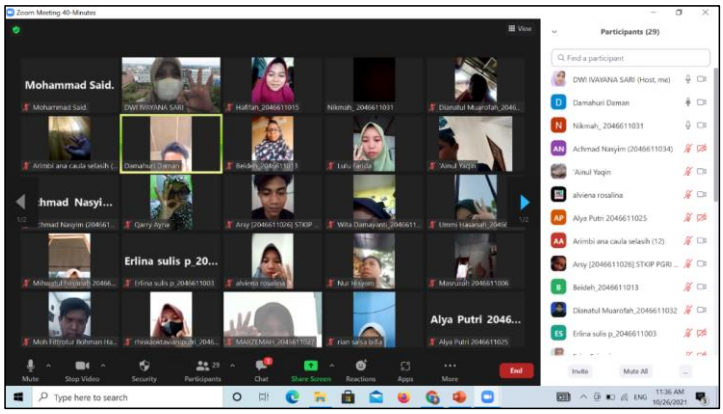

Figure 5. Closing Session in The Webinar Class (Zoom)

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Figure 6. Discussion Session in WAG

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The first meeting was conducted in asynchronous learning through e-learning classes. Preservice teachers filled out attendance lists, accessed content in e-learning, studied teaching materials, responded to discussion forums, did assignments, and uploaded answers in e-learning. Synchronous learning was done through WAG. This was done if preservice teachers didn't understand and needed to ask. The duration of the meeting was 10.30 - 13.00.

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The second meeting was implemented in synchronous learning through a webinar class using the zoom application. Preservice teacher attendance was done by filling out the attendance list in e-learning. The lecturer explained the material in PowerPoint and video. Preservice teachers could ask and answer directly and then discussed this through this zoom application. The activity was continued with asynchronous learning in e-learning class, where preservice teachers downloaded tasks in e-

learning and uploaded answers in e-learning. Learning continued until the fourth, fifth, sixth, seventh meetings. Next, at the 8th meeting, students worked on mid-test questions through synchronous learning in webinar class. Previously, preservice teachers downloaded questions in e-learning.

Data collection continued until the fifteenth meeting. The learning implementation on the ninth to fifteenth meetings was implemented asynchronously and synchronously like previous meetings. At the 16th meeting, preservice teachers worked on final-test questions through synchronous learning in webinar class. Previously, preservice teachers downloaded questions in e-learning.

The preservice teacher's learning outcomes and improvement of learning outcomes

The mid-test result showed that 17 of 23 preservice teachers achieved scores of more than 65% of the total score. This showed that 87% of preservice teachers completed studying. This showed that there was an improvement of preservice teachers' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to preservice teachers' learning outcomes through just WAG. While results of the final test showed that all preservice teachers achieved a score of more than 65% of the total score. This showed that 100% of preservice teachers have completed studying. This showed that there was an improvement of preservice teachers' learning outcomes in elementary linear algebra material after online learning through asynchronous and synchronous learning was implemented compared to preservice teachers' learning outcomes through just WAG. Furthermore, final-test results had increased compared to mid-test results.

Based on the results of the research above, it showed that preservice teachers' learning outcomes in elementary linear algebra material using asynchronous and synchronous learning approaches had increased. The results of this study were in line with the results of Zaharah, Kirilova & Windarti's (2020) research which stated that learning using E-learning brings progress and innovation to education in Indonesia because almost 75% of students conducted online learning simultaneously during the covid-19 epidemic. Sindu & Paramartha (2018) argued that theoretically, the use of instructional media based on video and slide synchronization system facilitated students at the time of learning, that is, at the time of material discussion and it made the use of instructional time more effective.

The preservice teacher's responses

After all, learning was implemented, preservice teachers were asked to fill out a subject's response questionnaire to online learning through asynchronous and synchronous learning in elementary linear algebra material. The subject's response questionnaire could be accessed by google form in link https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN. The results of preservice teachers' responses to the knowledge aspect can be seen in Figure 7.

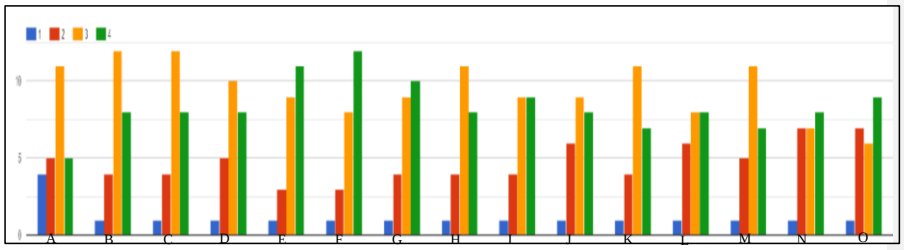

Figure 7. The results of preservice teachers' responses to the knowledge aspect

There are 15 indicators at the knowledge aspect, namely, a). My knowledge of elementary linear algebra is very good, b). I can explain the meaning of the linear equation system, c). I can explain the Gauss Jordan elimination method, d). I can solve the system of linear equations with Gauss Jordan elimination, e). I can explain the meaning of matrix, f). I can determine operation result of two matrices, g). I can explain the meaning of determinant, h). I can determine the determinant of a matrix by using cofactor expansion, i). I can determine the determinant of a matrix by using row reduction, j). I can prove that a set is a vector space, k). I can prove that a set is a subspace of a vector space, l). I can show that some vectors are linear combinations of a vector, m). I can show that a vector spans the set, n). I can show a linearly independent set or linearly dependent, o). I can show that a set is the basis and dimension of a subspace in a vector space. Likert scale, 1=less, 2=enough, 3=good, 4=very good

Based on analysis results of preservice teacher's responses on knowledge aspect, it showed that (1) preservice teacher's knowledge of elementary linear algebra material was good category, because preservice teacher's average respon was 3, (2) preservice teacher's ability to explain the meaning of linear equation system was good category, because preservice teacher's average respon was 3, (3) preservice teacher's ability in explaining Gauss Jordan Elimination method was good category, because preservice teacher's average respon was 3, (4) preservice teacher's ability to solve a system of linear equations with Gauss Jordan elimination was good category, because preservice teacher's average respon was 3, (5) preservice teacher's ability to explain the meaning of matrix was good category, because preservice teacher's average respon was 3, (6) preservice teacher's ability to determine operation result of two matrices was good category, because preservice teacher's average respon was 3, (7) preservice teacher's ability to explain the meaning of determinants was good category, because preservice teacher's average respon was 3, (8) preservice teacher's ability to determine determinant of a matrix using cofactor expansion was good category, because preservice teacher's average respon was 3, (9) preservice teacher's ability to determine determinant of a matrix using row reduction was good category, because preservice teacher's average respon was 3, (10) preservice teacher's ability to prove a set was a vector space was good category, because preservice teacher's average respon was 3, (11) preservice teacher's ability to prove that a set was a subspace of

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another set was good category, because preservice teacher's average respon was 3, (12) preservice teacher's ability to show that a set was a linear combination of other sets was good category, because preservice teacher's average respon was 3, (13) preservice teacher's ability to show that an element spans a set was good category, because preservice teacher's average respon was 3, (14) preservice teacher's ability to show show a linearly independent set or linearly dependent was good category, because preservice teacher's average respon was 3, (15) preservice teacher's ability to show that a set was basis and dimension of a subspace in a vector space were good category, because preservice teacher's average respon was 3. This showed that preservice teachers' response to the knowledge aspect was positive.

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The result of preservice teachers' responses to the knowledge aspect supported the result of improving preservice teachers' learning outcomes in the previous analysis. These results indicated that preservice teachers had good knowledge of elementary linear algebra material after asynchronous and synchronous learning was implemented. This was because the availability of teaching materials in e-learning or e-learning classes was very helpful for preservice teachers in understanding material before they discussed it in webinar classes. Therefore, mathematics learning would not experience difficulties during this pandemic if the material presentation had been presented in an e-learning class. This was under the opinion of Das (2020) who stated that mathematics education would be easier if virtual math classrooms can be presented to students through the internet. Furthermore, Noviani (2021) recommended that e-learning design was under learning objectives to minimize barriers.

The result of preservice teachers' responses to attitudes aspect in online learning (synchronous and asynchronous learning) can be seen in Figure 8 below.

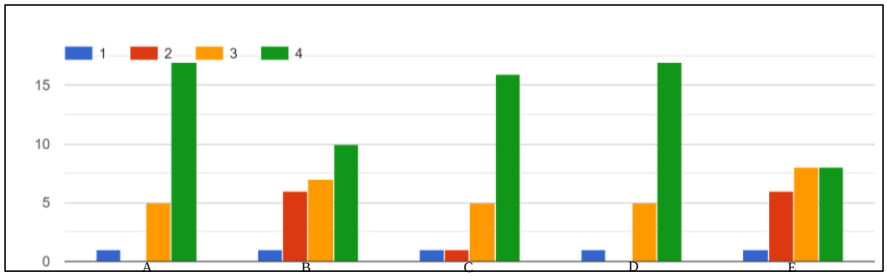

Figure 8. The result of preservice teachers' responses to attitudes aspect in online learning (synchronous and asynchronous learning)

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There are 5 indicators at attitudes aspect in online learning (synchronous and asynchronous learning), namely, a). I always download teaching materials in e-learning, b). I always respond to discussion forums on e-learning, c). I always download tasks in e-learning, work tasks, and upload answers in e-learning, d). I always take webinar classes, e). I actively ask and answer during webinar class. Likert scale, 1=less, 2=enough, 3=good, 4=very good.

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Based on analysis results of preservice teacher's responses on attitudes aspect, it showed that (1) preservice teacher's habits in downloading teaching materials in e-learning were a good category, because preservice teacher's average respon was 4, (2) preservice teacher's habits in responding to discussion forums in e-learning were good category because preservice teacher's average respon was 3, (3) preservice teacher's habits in downloading tasks in e-learning, work tasks and uploading answers in e-learning were good category because preservice teacher's average respon was 4, (4) preservice teacher's habits in taking webinar classes were good category because preservice teacher's average respon was 4, (5) preservice teacher's habits to actively ask and answer during synchronous classes were good category because preservice teacher's average respon was 3. This showed that preservice teachers' response to attitudes aspect was positive.

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Preservice teachers' attitude in asynchronous and synchronous learning was one of the factors of positive preservice teachers' knowledge of elementary linear algebra. Preservice teachers were enthusiastic about this online learning. Preservice teachers were active in online learning, both asynchronous and synchronous learning. The results of this study were in line with the results of Wijaya's research (2020) which resulted in there was a good student learning attitude towards the learning video. Students felt that learning the video was very interesting yet effective as they were able to understand the concept taught.

The result of preservice teachers' responses to the use of e-learning and webinar classes applications can be seen in Figure 9 and Figure 10 below.

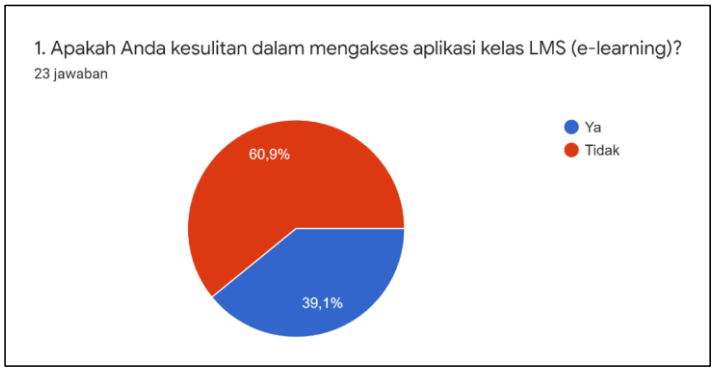

Figure 9. The result of preservice teachers' responses to the use of e-learning class applications

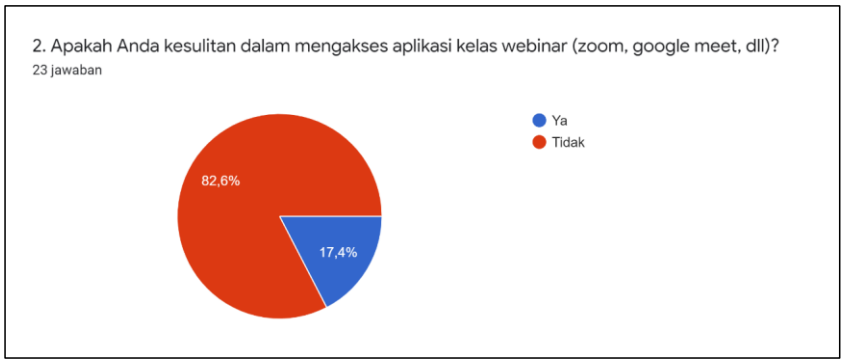

Figure 10. The result of preservice teachers' responses to the use of webinar class application.

Based on Figure 9, showed that 60.9% of preservice teachers had no difficulty in using e-learning class applications. While Figure 10 showed that 82.6% of preservice teachers had no difficulty in using webinar class applications. This showed that preservice teachers' skills in using e-learning and webinar classes applications were effective.

The result of preservice teachers' responses to the use of e-learning and webinar classes applications supported preservice teachers' attitudes towards online learning through asynchronous and synchronous learning. Preservice teachers had no difficulty in participating in e-learning and webinar classes. This showed that preservice teachers were ready to face the industrial 4.0 period as suggested by Mairing, et. al (2021).

Furthermore, the result of preservice teachers' responses to the usefulness of e-learning and webinar classes applications can be seen in Figure 11 and Figure 12 below.

Figure 11. The result of preservice teachers' responses to the usefulness of e-learning class application

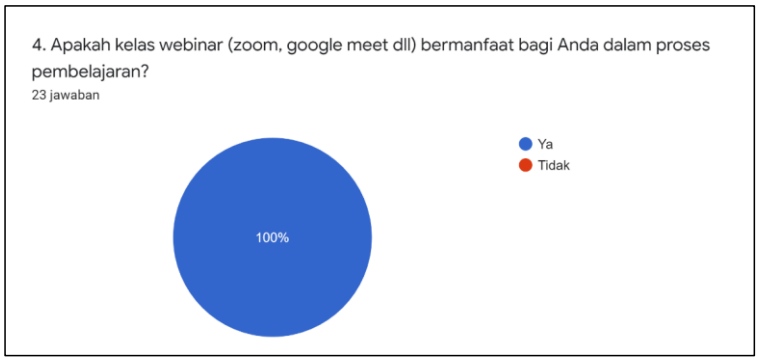

Figure 12. The result of preservice teachers' responses to the usefulness of webinar class application

Based on Figures 11 and 12, showed that 100% of preservice teachers responded that e-learning and webinar classes were beneficial for them. The result of preservice teachers' responses to the usefulness of e-learning and webinar classes applications also supported preservice teachers' attitudes towards online learning through asynchronous and synchronous learning. Preservice teachers felt that e-learning and webinar classes were very useful so they were enthusiastic and active in online learning. This was in Amiti's opinion (2020) which stated that the overall study results showed that even though there could be a preference for both e-learning methods, both synchronous and asynchronous e-learning methods if combined right, it could help teachers and learners, have a successful course and results.

Figure 13 below showed the frequency of preservice teachers accessing e-learning classes in a week.

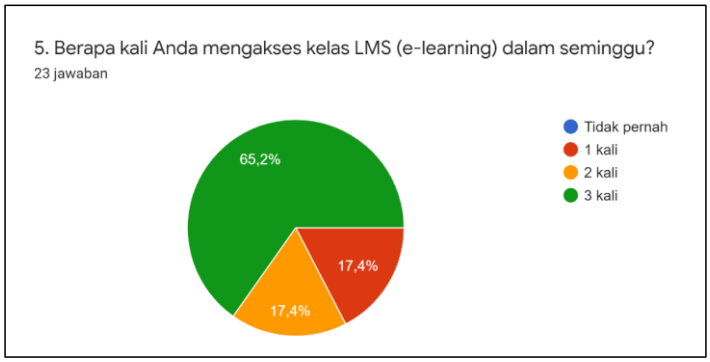

Figure 13. The result of preservice teachers' responses to the frequency of accessing e-learning class in a week. There are 3 options, namely 1 time, 2 times, or 3 times in a week.

Based on Figure 13, there were 65.2% of preservice teachers accessed e-learning classes 3 times a week, 17.4% of preservice teachers accessed e-learning classes 1 or 2 times a week. These

results indicated that they were enthusiastic and active in online learning through asynchronous and synchronous learning. More than 50% of preservice teachers accessed e-learning 3 times a week. It reflected that they made good use of this e-learning facility to support their learning process. E-learning could provide everything needed to learn. This was in line with the opinion of Xie, Liu, Bhairma, Shim (2018) who stated that students preferred to use asynchronous learning because they could easily access it offline. In addition, the asynchronous learning model was useful for shy students and was not used in virtual discussions through computers. Raymond, Atsumbe, Okwori, and Jebba (2016) recommend that higher education institutions used innovative e-learning platforms and encouraged lecturers to not only used synchronous learning in teaching but also used asynchronous learning.

Based on results, researcher recommends lecturers in teacher education program can apply online learning by synchronous and asynchronous learning through e-learning, because it affects Pedagogical Content Knowledge (PCK) of preservice teacher. PCK is a combination of two elements, namely Content Knowledge (CK) and Pedagogical Knowledge (PK). Saifudin and Sukma (2018) stated that two elements were very important for preservice teacher as educational professionals. Content Knowledge (CK) was understanding and mastery of material in shaping and influencing students' knowledge and thinking processes. Zubainur, Dazrulliza & Marwan (2017) stated that measuring preservice teachers' understanding of material is important to do, in order to help improve PCK of preservice teacher. But, Content Knowledge (CK) must be balanced with Pedagogical Knowledge (PK) or how to teach and manage class, in order to create effective learning.

In the millennial 4.0, teachers are said to be professional if they are able to manage class by virtual learning. Based on research results of Siregar, Solfitri & Siregar (2021) stated that preservice teaachers have already had quite good perception of online learning while attending lectures during the COVID-19 pandemic. Beside that, teachers are able to make teaching materials and assess student assignments by online, so that student learning increases. This is line with result of Keller, Neumann & Fischer (2017) that teacher's PCK mainly influences student learning. Therefore, PCK of preservice teachers can be developed by synchronous and asynchronous learning through e-learning. This is because understanding of material develops and is accustomed to using online learning support applications such as Zoom, Google Meet and Moodle.

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Conclusion

The results showed that the application of asynchronous learning and synchronous learning could improve preservice teachers' learning outcomes in online learning. It can be seen from classical completeness studying after mid-test was higher than classical completeness studying through just WAG. This also supported by the result of classical completeness studying after the final test was higher than classical completeness studying after the mid-test.

The questionnaire results showed that most of preservice teachers gave a positive response to asynchronous and synchronous learning. Preservice teachers' response to the knowledge aspect was positive, preservice teachers' attitude towards learning was positive, preservice teachers were able to access e-learning and webinars classes easily, preservice teachers thought that e-learning and webinar classes were very useful and helped their learning. Furthermore, preservice teachers often accessed e-learning to study materials and downloaded tasks, work tasks, and upload tasks' answers in e-learning.

Referring to the research results, synchronous learning and asynchronous learning through e-learning can be used by lecturers in teacher education program, not only in elementary linear algebra material but in other mathematics material, because it affects Pedagogical Content Knowledge (PCK) of preservice teacher. Preservice teachers have experience about online learning that combines synchronous and asynchronous learning through e-learning. This can provide knowledge for preservice teachers in developing online learning methods. Further research can apply asynchronous and synchronous learning with different learning activity designs. An example of a research objective is to compare the effectiveness of other online learning with asynchronous and synchronous learning on students' learning outcomes. If the pandemic is over, then the effectiveness of blended learning by combining directly face-to-face learning with asynchronous learning (e-learning) also needs to be researched. Research's focus can be done on 4Cs (critical thinking, creativity, communication, and collaboration) because 4 abilities are very much needed in this 4.0 era.

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HASIL REVIEW TAHAP 2

Note for paper 24759

Thank you for the revision. However, I want to give some input according to reviewers' comment so that this paper achieves the JDM standard, as follow

1. How author conclude that the treatment can improve preservice teachers' learning outcomes from mid test and posttest only?
2. Please connect implication to many information in introduction, or any information about the impact of e learning to preservice teachers' outcome. It is not suitable the findings connect to Pedagogical Content Knowledge (PCK) of preservice teacher. Please connect it also to learning in pandemic situation
3. Authors didn't revise reviewers' comment: The table 1 is too long, it should be less than 1 page. Please summarize the table.
4. Please change display data in Pie Diagram to Table
5. Please synchronize: abstract, finding, discussion, and conclusion
6. Please follow JDM template/author guidelines about how to write reference.

Aisyah, S., & Sari, D. I. (2021). Efektivitas Penggunaan Platform Google Meet terhadap Hasil Belajar Siswa. *JURNAL MathEdu (Mathematic Education Journal)*, *4*(1), 45–49. http://journal.ipts.ac.id/index.php/MathEdu/article/view/2313

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HASIL REVISI BERDASARKAN HASIL REVIEW TAHAP 2

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Synchronous and Asynchronous Learning by Using E-Learning for Preservice Teachers on Elementary Linear Algebra Material

Abstract. *The learning process changed from face-to-face to full-online, since COVID-19 pandemic in the end of 2019. In early 2020, one of teacher education program in Bangkalan, Indonesia implemented online learning through WhatsApp Group (WAG). However, the learning result showed that 75% of preservice teacher were not being complete in elementary linear algebra material. Online learning through asynchronous learning by using e-learning was one solution to solve the problem. However, synchronous learning needs to be implemented so that preservice teacher can face-to-face virtually with lecturers. The purpose of this study was to determine improvement in preservice teachers' learning outcomes and preservice teachers' responses to synchronous and asynchronous learning. The research design used was one group posttest-only design. 23 subjects were selected by clustered random sampling. Data were analyzed by descriptive statistical analysis. Results show that synchronous and asynchronous learning can improve preservice teachers' learning outcomes and most preservice teachers gave a positive response to synchronous and asynchronous learning. The combination of synchronous and asynchronous learning by using e-learning is one solution for online learning during Covid-19 pandemic. Higher education institutions provide innovative e-learning platforms and encouraged lecturers to not only used synchronous learning in teaching but also to combine it with asynchronous learning by using e-learning.*

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

Abstract. *Proses pembelajaran berubah dari tatap muka menjadi fullonline, sejak pandemic covid-19 di akhir tahun 2019. Di awal tahun 2020, salah satu perguruan tinggi keguruan di Bangkalan, Indonesia melaksanakan pembelajaran daring melalui WhatsApp Group (WAG). Namun pembelajaran ini mengakibatkan 75% mahasiswa calon guru tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui asynchronous learning dengan memanfaatkan e-learning menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, synchronous learning perlu diterapkan agar mahasiswa calon guru dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa calon guru dan respon mahasiswa calon guru terhadap synchronous and asynchronous learning. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa calon guru yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa synchronous dan asynchronous learning dapat meningkatkan hasil belajar mahasiswa calon guru dan sebagian besar mahasiswa calon guru memberikan respon positif terhadap pembelajaran synchronous dan asynchronous learning. Kombinasi synchronous dan asynchronous learning adalah salah satu solusi untuk pembelajaran daring selama pandemic Covid-19. Perguruan tinggi menyediakan platform e-learning yang inovatif dan mendorong dosen tidak hanya menggunakan synchronous learning dalam mengajar tetapi juga mengkombinasikan dengan asynchronous learning melalui e-learning.*

Keywords*: Synchronous learning, asynchronous learning, e-learning, mahasiswa calon guru, aljabar linear elementer*

Introduction

At the end of 2019, Word was shaken by emerging a new coronavirus called Novel Corona Virus (2019-nCoV). This virus was originally discovered in Wuhan China in December 2019. A very significant spread to all countries in the world occurred in early 2020, including Indonesia. This was the cause of the covid-19 pandemic in Indonesia.

The covid-19 pandemic in Indonesia had a big impact in various fields, ranging from Health, Economy, and Education fields. In education fields, educational's institutions ranging from Kindergarten to Universities didn't implement face-to-face learning to reduce personal contact. Furthermore, Azhari & Fajri (2020) stated that to avoid the spread of Covid-19, the government gave the policy to close classrooms without stopping learning, so that schools implemented distance learning. Since 2020, learning had changed from face-to-face learning to online learning by using information technology (Rehman & Fatima, 2021).

In early 2020, online learning was implemented at STKIP PGRI Bangkalan through WhatsApp Group (WAG). However, learning through WAG had many shortcomings, especially in an elementary linear algebra course. Based on learning outcomes data, it showed that 75% of preservice teacher didn't complete studying. This means that 20% of preservice teacher had completed studying. This learning outcome had decreased significantly compared to results of previous studies regarding the effectiveness of learning in an elementary linear algebra course, which showed that 86% of students had completed their studies (Sari, 2016).

Whereas elementary linear algebra course is a basic course that must be mastered by students because elementary linear algebra course is a prerequisite course for studying further courses such as abstract algebra. This is under the opinion of Suryaningsih (2016) & Ruswana (2019) who stated that elementary linear algebra was a basic subject that must be mastered by low-level students. If students can master material of elementary linear algebra, then students can easily learn other subjects.

Based on the explanation above, online learning needs to be changed. It can be implemented by using asynchronous learning. Skylar (2009) stated that Asynchronous courses provide students with a flexible environment that was self-paced with students accessing course content using a variety of tools. Students were not restricted to a set day/time for communicating, and it allowed students more time to prepare a response to a set of directions or questions. Asynchronous learning is implemented by using the university's e-learning with moodle platform. According to Hambrecht (in Ogbonna, Ibezim & Obi, 2019) e-learning was defined as 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. E-learning contains content for one semester are materials,

discussion forums, and assignments. Yuhasriyati et.al (2020) stated that the use of e-learning may force educational processes to run faster in terms of accessibility and quality. The use of e-learning was also very influential on learning activities and students' learning outcomes (Fitriani & Nurjannah, 2019). Furthermore, Lin, Tseng & Chiang (2017) explained that students gave positive feedback on the use of Moodle learning platform for mathematics after experiencing blended learning.

Before pandemic, e-learning can be implemented in blended learning, namely combining online learning through e-learning with face-to-face learning directly. There were several studies had shown that blended learning showed significant success in improving students' learning outcomes. As research results by Lin, Tseng & Chiang (2017) stated that ANCOVA and MANCOVA analyses showed that blended learning experience benefitted students in the experimental group by having a positive effect not only on learning outcomes but also on their attitudes toward studying mathematics in a blended environment. These results are in line with the research of Sukma & Priatna (2020) which explained that the implementation of blended learning in Mathematics had the potential to improve student's critical thinking skills (CTS).

However, during this pandemic learning was implemented fully online (Trenholm & Peschke, 2020), which means that learning was implemented using e-learning without face-to-face directly. Therefore, synchronous learning was an alternative to virtual face-to-face learning between lecturer and students. Shi & Morrow in Skylar (2009) stated that in real-time synchronous courses, the instructor leads the learning, and all learners were logged on simultaneously and communicated directly with each other.

Synchronous learning at STKIP PGRI Bangkalan was implemented by using zoom application, google meet application, etc. The aims of synchronous learning to students could understand the material so that student's learning outcomes were good. This is in line with the research results of Aisyah and Sari (2021) which stated that the use of the Google meet platform could improve students' learning outcomes.

Therefore, online learning using asynchronous learning through e-learning and synchronous learning through the virtual conference was an alternative in implementing elementary linear algebra learning. Many previous research results showed the success of asynchronous and synchronous learning. Research by Ogbonna & Ibezim (2019) showed that synchronous and asynchronous e-learning modes increased the cognitive academic achievement of students in word processing.

In the middle of 2020, STKIP PGRI Bangkalan took a policy related to online learning implemented in 2 ways, namely asynchronous and synchronous learning. However, synchronous learning was implemented between 7-8 meetings. While asynchronous learning was implemented

in full, namely 14-16 meetings. Asynchronous learning was implemented in e-learning classes, while synchronous learning was implemented in webinar classes (zoom, google meet, etc.).

However, this implementation's change of online learning needs to be evaluated for its implementation. One of them was the preservice teacher's perspective because they were objects of learning. Their success was the output of learning application by the lecturer. Based on this explanation, the aims of this study were 1) to determine the improvement of preservice teachers' learning outcomes through synchronous and asynchronous learning by using e-learning on elementary linear algebra material and 2) to determine preservice teachers' responses to synchronous and asynchronous learning by using e-learning.

Method

Research Design

The author applied treatment to the participant's group, to determine the improvement of preservice teachers' learning outcomes on elementary linear algebra material and preservice teachers' responses to synchronous and asynchronous learning by using e-learning. Asynchronous learning was implemented in e-learning classes with moodle platform. Meanwhile, synchronous learning was implemented in the webinar class using zoom application.

The learning effectiveness was measured using two types, namely tests and a list of questions. Instruments were given to participants after learning implementation. The author applied to learn in one class by synchronous and asynchronous learning by using e-learning. Therefore, this study was an experimental study using a one-group posttest-only design.

Participants

The population in this study was all preservice teachers of the mathematics education study program at STKIP PGRI Bangkalan in the odd academic year 2021/2022, totaling 34 preservice teachers. The author took a sample using clustered random sampling so that there were 23 preservice teachers as a sample. The sample was heterogeneous based on gender and initial mathematical ability. Initial math skills were taken from calculus scores in the previous semester.

Instruments

Research instruments were lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of sixteen meetings, eight meetings were implemented in e-learning class and webinar class (zoom), such as 2^{th}, 4^{th}, 6^{th}, 8^{th}, 10^{th}, 12^{th}, 14^{th}, 16^{th}. The eight more meetings were implemented in e-learning class and WhatsApp Group (WAG), such as 1^{th}, 3^{th}, 5^{th}, 7^{th}, 9^{th}, 11^{th}, 13^{th}, 15^{th}. The author implemented 8 webinar classes because it was under campus rules that implementation of synchronous learning through webinar classes was implemented 7-8 times, this was due to constraints in purchasing internet quota. In

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this case, the 8th meeting (mid-test session) and the 16th meeting (final-test session) were conducted in e-learning class and webinar class (zoom).

The author gave mid-test and final-test at the 8th and 16th meetings. Test questions were developed according to the material in the lesson plan. To get a valid mid-test and final-test, used 3 validities, namely construct validity, content validity, and face validity. Construct validity was done by ensuring that results of mid-test and final-test actually measure preservice teachers' abilities in elementary linear algebra and not other variables. Content validity was done by reviewing and making mid-test and final-test grids. Grids covered questions and prepared question indicators so that no indicators were missed. The mid-test and final-test grids can be seen in Table 1 and Table 2. Face validity was done by 2 (two) experts. Experts evaluated elements of concept truth, rules for writing questions, displays for example writing symbols and mathematical formulas, punctuation marks, pictures and language. The face validation average result for mid-test was 4.17. The face validation average result for final-test was 4.33. It means that mid-test and final-test were 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 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 not both.	√			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 so that the system of linear equations, 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 inverse matrix by the inverse algorithm	√			C2	Inverse matrix	7	15
8	Given several matrices, students can determine upper triangular matrix, lower triangular matrix, and diagonal matrix	√			C2	Matrix	8	10

Tabel 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 matrix determinant by using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system of linear equations 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 can determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that three 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 basis S of $M_{2,2}$ and students can determine dimensions of the S subspace of $M_{2,2}$	√			C3	Basis and dimension	8	10

The author developed a questionnaire to measure preservice teachers' responses to the approach. To get a valid questionnaire, used 3 validities, namely construct validity, content validity, and face validity. Construct validity was done by ensuring that results of questionnaire actually measure preservice teachers' responses to synchronous and asynchronous learning by using e-learning. Content validity was done by reviewing and making questionnaire grids. Grids covered questions and prepared question indicators so that no indicators were missed. Aspects of the questionnaire and indicators can be seen in Table 3. Face validity was done by 2 (two) experts. Experts evaluated elements of concept truth, rules for writing questions, displays for language. The face validation average result for questionnaire was 4.83. The statements on the questionnaire used a Likert scale.

Table 3. Aspects and Indicators of The Questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	Student's knowledge of elementary linear algebra material through online learning
			Student's ability to understand every elementary linear algebra material through online learning
			Student's ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in Asynchronous	Student's response when independently learning through learning resources in e-learning

		and synchronous learning	Student's responses when responding to discussion forums
			Student's responses when downloading assignments in e-learning, work it and upload answers in e-learning
			Student's responses about taking synchronous learning
			Student responses when discussing through webinar classes
			Frequency of students accessing e-learning
3.	E-learning dan Webinar classes applications	Ease of access and usefulness for students	Ease of accessing e-learning class application
			Ease of accessing webinar class application
			The usefulness of accessing e-learning class application
			The usefulness of accessing e-learning class application

The Procedure of Data Collection

Data collection was done by giving tests and questionnaire. The instrument was given online by using e-learning and google form. Learning implementation by using asynchronous and synchronous learning in line with lesson plan design.

Data Analysis

Data analysis in this study used descriptive statistical analysis because the aim was to explain and provide an overview of characteristics of a series of data, without doing any generation. After the test result data and preservice teacher's response data were collected, authors analyzed data as follows:

1. Analysis of test result data

   Data analysis of test results was measured using a completeness test. This completeness test consists of an individual completeness test and a classical completeness test. The Ministry of Education and Culture categorizes subjects' scores into 5 categories 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

   Furthermore, Widoyoko (2009) determines 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

   Based on the criteria above, the author established criteria for individual completeness, namely that preservice teachers were said to have completed learning if they got a score of 65% of the total score. While classical completeness criteria were 80% of preservice teachers have completed their studies. Improved learning outcomes were achieved if preservice teachers' learning outcomes after mid-test were higher than preservice teachers' learning

outcomes before being given treatment. Then preservice teachers' learning outcomes of the final-test were higher than preservice teachers' learning outcomes of the mid-test.

2. Analysis of preservice teacher's response data

   Preservice teacher's response data obtained from questionnaires consists of 2 types. This was because questions from the questionnaire consist of 2 kinds, namely questions with 4 answers (1,2,3,4) and questions with 2 answers (yes and no).

   For the first question, the criteria were as follows:

   1, 00 ≤ average < 1, 50: less
   1, 50 ≤ average < 2, 50: enough
   2, 50 ≤ average < 3, 50: good
   3, 50 ≤ average ≤ 4, 00: very good

   Preservice teachers ' responses were said to be positive if they were in good and very good categories.

   For the second question, preservice teachers' responses were said to be effective if more than 50% of students' responses were good.

Results and Discussion

The asynchronous and synchronous learning activities

Data collection was implemented for the first time on Tuesday, October 5, 2021, according to the class schedule. Before the first meeting began, the lecturer filled out e-learning content. Required content, starting from the introductory session, 1st–7th sessions, 9th–15th sessions, 8th sessions, and 16th sessions. The introductory session contains 1) explanation of course descriptions, 2) course achievements, 3) introduction forum (lecturer introduction video), 4) lecture contracts, 5) libraries, 6) attendance list. So, 1th–7th sessions and 9th–15th sessions each contain 1) greetings and explanation sessions, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, 6) links to webinar class meetings. So, the 8th sessions and 16th sessions contain 1) greetings and explanations sessions, 2) mid-test questions or final-test questions according to the specified format. The display of e-learning can be seen in Figures 1, 2 and 3, discussion and closing sessions can be seen in Figure 4 and 5, discussion sessions in WAG can be seen in Figure 6.

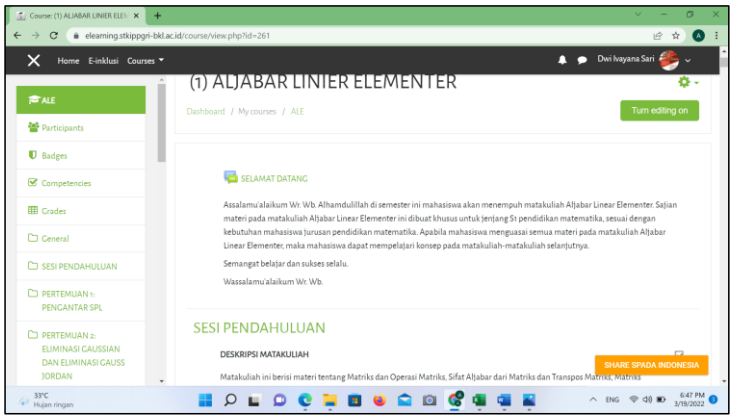

Figure 1. Front View of Elementary Linear Algebra in E-learning

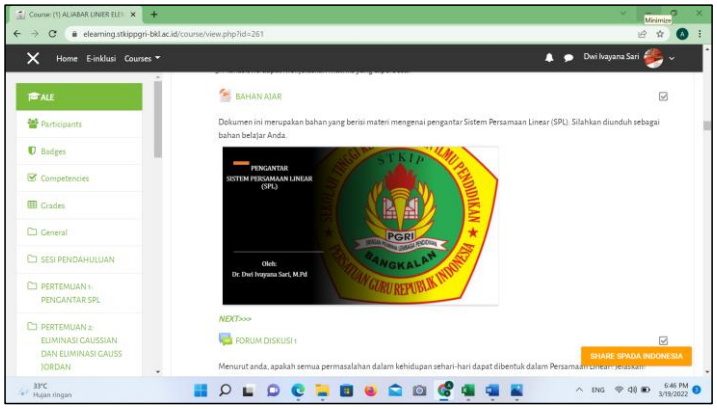

Figure 2. Content Display at 1th Meeting in E-learning

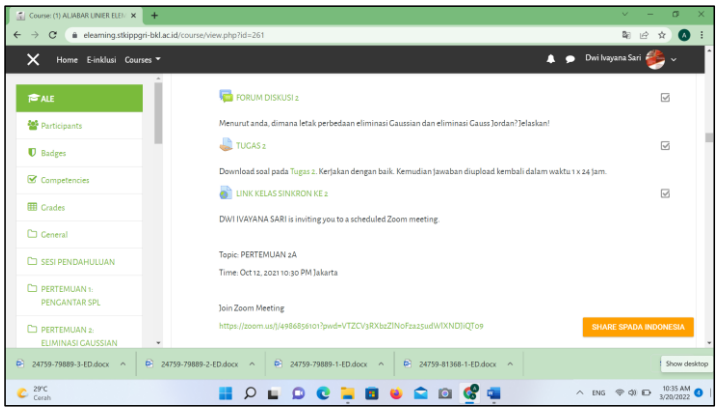

Figure 3. Content Display at 2th Meeting in E-learning

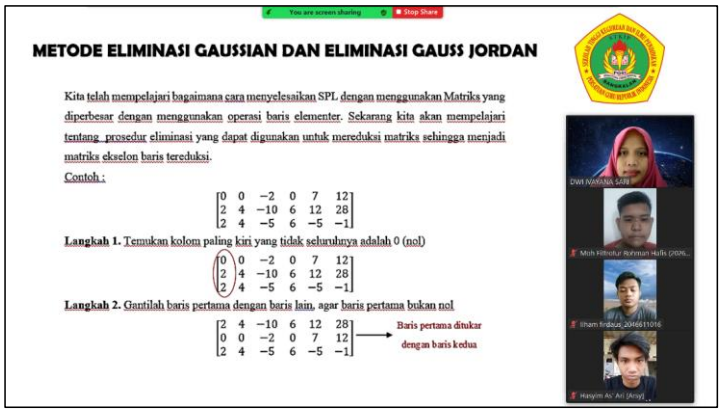

Figure 4. Discussion Session in The Webinar Class (Zoom)

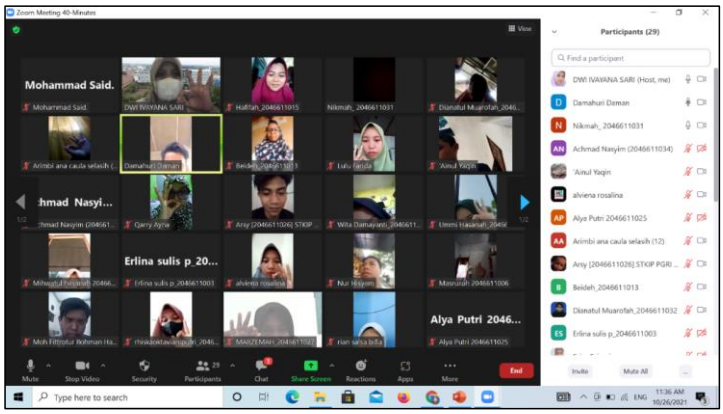

Figure 5. Closing Session in The Webinar Class (Zoom)

Figure 6. Discussion Session in WAG

The first meeting was conducted in asynchronous learning through e-learning classes. Preservice teachers filled out attendance lists, accessed content in e-learning, studied teaching materials, responded to discussion forums, did assignments, and uploaded answers in e-learning. Synchronous learning was done through WAG. This was done if preservice teachers didn't understand and needed to ask. The duration of the meeting was 10.30 - 13.00.

The second meeting was implemented in synchronous learning through a webinar class using the zoom application. Preservice teacher attendance was done by filling out the attendance list in e-learning. The lecturer explained the material in PowerPoint and video. Preservice teachers could ask and answer directly and then discussed this through this zoom application. The activity was continued with asynchronous learning in e-learning class, where preservice teachers downloaded tasks in e-learning and uploaded answers in e-learning. Learning continued until the fourth, fifth, sixth, seventh meetings. Next, at the 8th meeting, students worked on mid-test questions through synchronous learning in webinar class. Previously, preservice teachers downloaded questions in e-learning.

Data collection continued until the fifteenth meeting. The learning implementation on the ninth to fifteenth meetings was implemented synchronously anf asynchronously like previous meetings. At the 16th meeting, preservice teachers worked on final-test questions through synchronous learning in webinar class. Previously, preservice teachers downloaded questions in e-learning.

The preservice teacher's learning outcomes and improvement of learning outcomes

The mid-test result showed that 17 of 23 preservice teachers achieved scores of more than 65% of the total score. This showed that 87% of preservice teachers completed studying. This showed that there was an improvement of preservice teachers' learning outcomes in elementary linear algebra material after online learning through synchronous and asynchronous learning by using e-learning was

implemented compared to preservice teachers' learning outcomes through just WAG. While results of the final test showed that all preservice teachers achieved a score of more than 65% of the total score. This showed that 100% of preservice teachers have completed studying. This showed that there was an improvement of preservice teachers' learning outcomes in elementary linear algebra material after online learning through synchronous and asynchronous learning by using e-learning was implemented compared to preservice teachers' learning outcomes through just WAG. Furthermore, final-test results had increased compared to mid-test results.

Based on the results of the research above, it showed that preservice teachers' learning outcomes in elementary linear algebra material through synchronous and asynchronous learning by using approaches had increased. The results of this study were in line with the results of Zaharah, Kirilova & Windarti's (2020) research which stated that learning using e-learning brings progress and innovation to education in Indonesia because almost 75% of students conducted online learning simultaneously during the covid-19 epidemic. Sindu & Paramartha (2018) argued that theoretically, the use of instructional media based on video and slide synchronization system facilitated students at the time of learning, that is, at the time of material discussion and it made the use of instructional time more effective. This shows that the combination of synchronous and asynchronous learning by using e-learning is one of the solutions for online learning during the Covid-19 pandemic.

The preservice teacher's responses

After all, learning was implemented, preservice teachers were asked to fill out a subject's response questionnaire to online learning through through synchronous and asynchronous learning by using e-learning in elementary linear algebra material. The subject's response questionnaire could be accessed by google form in link https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN. The results of preservice teachers' responses to the knowledge aspect can be seen in Table 4.

Table 4. The Results of Preservice Teachers' Responses to The Knowledge Aspect

Commented [A3]: I have presented in table form

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	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 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 set or linearly dependent	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

Based on analysis results of preservice teacher's responses on knowledge aspect, it showed that (1) preservice teacher's knowledge of elementary linear algebra material was good category, because preservice teacher's average respon was 3, (2) preservice teacher's ability to explain the meaning of linear equation system was good category, because preservice teacher's average respon was 3, (3) preservice teacher's ability in explaining Gauss Jordan Elimination method was good category, because preservice teacher's average respon was 3, (4) preservice teacher's ability to solve a system of linear equations with Gauss Jordan elimination was good category, because preservice teacher's average respon was 3, (5) preservice teacher's ability to explain the meaning of matrix was good category, because preservice teacher's average respon was 3, (6) preservice teacher's ability to determine operation result of two matrices was good category, because preservice teacher's average respon was 3, (7) preservice teacher's ability to explain the meaning of determinants was good category, because preservice teacher's average respon was 3, (8) preservice teacher's ability to determine determinant of a matrix using cofactor expansion was good category, because preservice teacher's average respon was 3, (9) preservice teacher's ability to determine determinant of a matrix using row reduction was good category, because preservice teacher's average respon was 3, (10)

preservice teacher's ability to prove a set was a vector space was good category, because preservice teacher's average respon was 3, (11) preservice teacher's ability to prove that a set was a subspace of another set was good category, because preservice teacher's average respon was 3, (12) preservice teacher's ability to show that a set was a linear combination of other sets was good category, because preservice teacher's average respon was 3, (13) preservice teacher's ability to show that an element spans a set was good category, because preservice teacher's average respon was 3, (14) preservice teacher's ability to show show a linearly independent set or linearly dependent was good category, because preservice teacher's average respon was 3, (15) preservice teacher's ability to show that a set was basis and dimension of a subspace in a vector space were good category, because preservice teacher's average respon was 3. This showed that preservice teachers' response to the knowledge aspect was positive.

The result of preservice teachers' responses to the knowledge aspect supported the result of improving preservice teachers' learning outcomes in the previous analysis. These results indicated that preservice teachers had good knowledge of elementary linear algebra material after synchronous and asynchronous learning by using e-learning was implemented. This was because the availability of teaching materials in e-learning or e-learning classes was very helpful for preservice teachers in understanding material before they discussed it in webinar classes. Therefore, mathematics learning would not experience difficulties during this pandemic if the material presentation had been presented in an e-learning class. This was under the opinion of Das (2020) who stated that mathematics education would be easier if virtual math classrooms can be presented to students through the internet. Furthermore, Noviani (2021) recommended that e-learning design was under learning objectives to minimize barriers.

The result of preservice teachers' responses to attitudes aspect in online learning (synchronous and asynchronous learning by using e-learning) can be seen in Table 5 below.

Table 5. The Result of Preservice Teachers' Responses to Attitudes Aspect in Online Learning (Synchronous and Asynchronous Learning by Using E-learning)

Commented [A4]: I have presented in table form

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 in e-learning	1	0	5	17	23	1	0	15	68	4	Good
2	I always respond to discussion forums on e-learning	1	5	7	10	23	1	10	21	40	3	Good
3	I always download tasks in e-learning, work tasks, and upload answers in e-learning	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 and answer during webinar class	1	6	8	8	23	1	12	24	32	3	Good

Based on analysis results of preservice teacher's responses on attitudes aspect, it showed that (1) preservice teacher's habits in downloading teaching materials in e-learning were a good category, because preservice teacher's average respon was 4, (2) preservice teacher's habits in responding to discussion forums in e-learning were good category because preservice teacher's average respon was 3, (3) preservice teacher's habits in downloading tasks in e-learning, work tasks and uploading answers in e-learning were good category because preservice teacher's average respon was 4, (4) preservice teacher's habits in taking webinar classes were good category because preservice teacher's average respon was 4, (5) preservice teacher's habits to actively ask and answer during synchronous classes were good category because preservice teacher's average respon was 3. This showed that preservice teachers' response to attitudes aspect was positive.

Preservice teachers' attitude in synchronous and asynchronous learning by using e-learning was one of the factors of positive preservice teachers' knowledge of elementary linear algebra. Preservice teachers were enthusiastic about this online learning. Preservice teachers were active in online learning, both synchronous and asynchronous learning by using e-learning. The results of this study were in line with the results of Wijaya's research (2020) which resulted in there was a good student learning attitude towards the learning video. Students felt that learning the video was very interesting yet effective as they were able to understand the concept taught.

The result of preservice teachers' responses to the use of e-learning and webinar classes applications can be seen in Figure 7 and Figure 8 below.

Figure 7. The result of preservice teachers' responses to the use of e-learning class applications

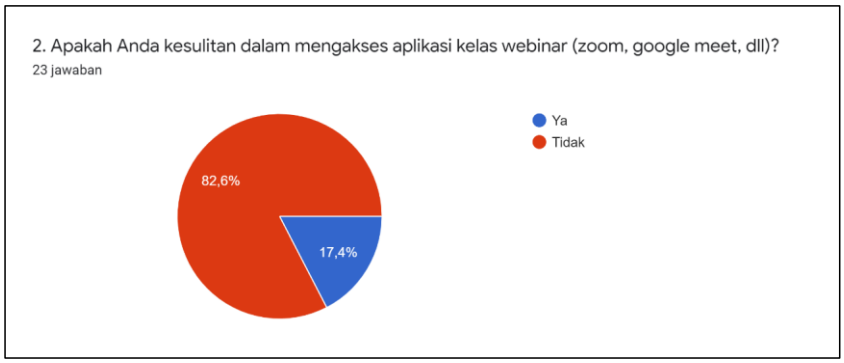

Figure 8. The result of preservice teachers' responses to the use of webinar class application

Based on Figure 7, showed that 60.9% of preservice teachers had no difficulty in using e-learning class applications. While Figure 8 showed that 82.6% of preservice teachers had no difficulty in using webinar class applications. This showed that preservice teachers' skills in using e-learning and webinar classes applications were effective.

The result of preservice teachers' responses to the use of e-learning and webinar classes applications supported preservice teachers' attitudes towards online learning through synchronous and asynchronous learning by using e-learning. Preservice teachers had no difficulty in participating in e-learning and webinar classes. This showed that preservice teachers were ready to face the industrial 4.0 period as suggested by Mairing, et. al (2021).

Furthermore, the result of preservice teachers' responses to the usefulness of e-learning and webinar classes applications can be seen in Figure 9 and Figure 10 below.

Figure 9. The result of preservice teachers' responses to the usefulness of e-learning class application

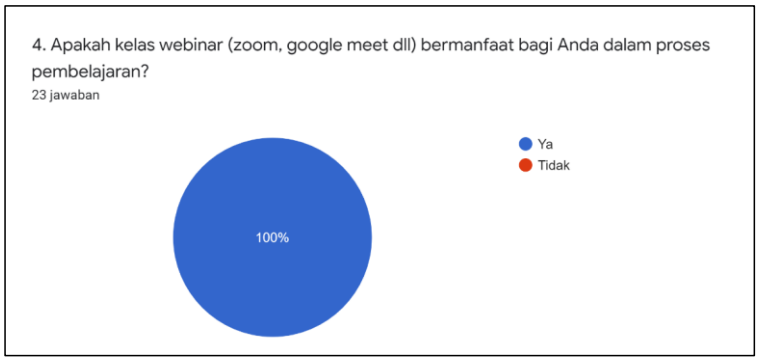

Figure 10. The result of preservice teachers' responses to the usefulness of webinar class application

Based on Figures 9 and 10, showed that 100% of preservice teachers responded that e-learning and webinar classes were beneficial for them. The result of preservice teachers' responses to the usefulness of e-learning and webinar classes applications also supported preservice teachers' attitudes towards online learning through synchronous and asynchronous learning by using e-learning. Preservice teachers felt that e-learning and webinar classes were very useful so they were enthusiastic and active in online learning. This was in Amiti's opinion (2020) which stated that the overall study results showed that even though there could be a preference for both e-learning methods, both synchronous and asynchronous e-learning methods if combined right, it could help teachers and learners, have a successful course and results.

Figure 11 below showed the frequency of preservice teachers accessing e-learning classes in a week.

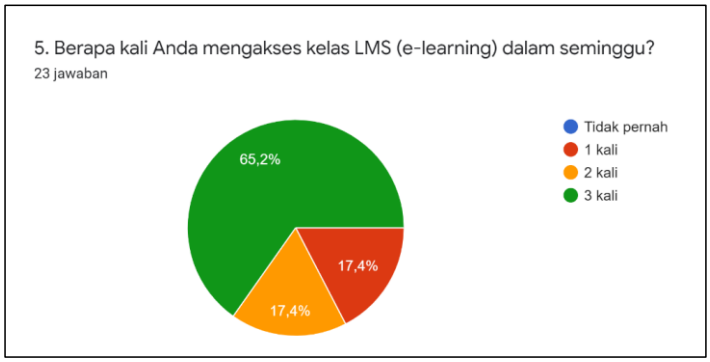

Figure 11. The result of preservice teachers' responses to the frequency of accessing e-learning class in a week. There are 3 options, namely 1 time, 2 times, or 3 times in a week.

Based on Figure 13, there were 65.2% of preservice teachers accessed e-learning classes 3 times a week, 17.4% of preservice teachers accessed e-learning classes 1 or 2 times a week. These

results indicated that they were enthusiastic and active in online learning through synchronous and asynchronous learning by using e-learning. More than 50% of preservice teachers accessed e-learning 3 times a week. It reflected that they made good use of this e-learning facility to support their learning process. E-learning could provide everything needed to learn. This was in line with the opinion of Xie, Liu, Bhairma, Shim (2018) who stated that students preferred to use asynchronous learning because they could easily access it offline. In addition, the asynchronous learning model was useful for shy students and was not used in virtual discussions through computers. Raymond, Atsumbe, Okwori, and Jebba (2016) recommend that higher education institutions used innovative e-learning platforms and encouraged lecturers to not only used synchronous learning in teaching but also used asynchronous learning by using e-learning.

Referring to the research results, the combination of synchronous learning and asynchronous learning by using e-learning is an alternative online learning method that can be applied by lecturers in teaching mathematics material during the Covid-19 pandemic. This is because 1) the availability of teaching materials and assignments in e-learning class (asynchronous learning) is very helpful for preservice teachers in understanding material before they discussed it in webinar class (synchronous learning). So that, synchorous learning becomes effective, because preservice teacher has studied material, downloaded tasks, and done tasks in e-learning, 2) e-learning and webinar classes are not difficult to access or use. Therefore, higher education institutions used innovative e-learning platforms and encouraged lecturers to not only used synchronous learning in teaching but also used asynchronous learning (Raymond, Atsumbe, Okwori, and Jebba, 2016).

In the millennial 4.0, teachers are said to be professional if they are able to manage class by virtual learning. Based on research results of Siregar, Solfitri & Siregar (2021) stated that preservice teaachers have already had quite good perception of online learning while attending lectures during the COVID-19 pandemic. Beside that, teachers are able to make teaching materials and assess student assignments by online, so that student learning increases.

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Conclusion

The results showed that the application of asynchronous learning and synchronous learning could improve preservice teachers' learning outcomes in online learning. It can be seen from classical completeness studying after mid-test was higher than classical completeness studying through just WAG. This also supported by the result of classical completeness studying after the final test was higher than classical completeness studying after the mid-test.

The questionnaire results showed that most of preservice teachers gave a positive response to asynchronous and synchronous learning. Preservice teachers' response to the knowledge aspect was positive, preservice teachers' attitude towards learning was positive, preservice teachers were

able to access e-learning and webinars classes easily, preservice teachers thought that e-learning and webinar classes were very useful and helped their learning. Furthermore, preservice teachers often accessed e-learning to study materials and download tasks, do tasks, and upload tasks' answers in e-learning.

Referring to the research results, synchronous and asynchronous learning by using e-learning is an alternative online learning method that can be applied by lecturers in teaching mathematics material during the Covid-19 pandemic. Further researchers can apply synchronous and asynchronous learning through e-learning to critical thinking, creativity, communication, and collaboration (4Cs). And then if the pandemic is over, then the effectiveness of blended learning by combining directly face-to-face learning with asynchronous learning (e-learning) also needs to be researched. Research's focus can be done on 4Cs because 4 abilities are very much needed in this 4.0 era.

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HASIL REVIEW TAHAP 3

Student responses are not in a pie chart, combined into one table, then discussed per student response

Please ask a professional proofreader to help improve English

HASIL REVISI BERDASARKAN HASIL REVIEW TAHAP 3

Jurnal Didaktik Matematika
ISSN 2355-4185(p), 2548-8546(e)
DOI: 10.24815/jdm.vxix.xxxxx

The Application of Synchronous and Asynchronous Learning ~~by Using E~~using e-Learning ~~for Preservice Teachers~~ on Elementary Linear Algebra ~~Material~~for Preservice Teachers

Abstract. *~~The learning process~~ Learning activities were changed from face-to-face to full-online~~, since~~ due to the COVID-19 pandemic ~~in~~at the end of 2019. ~~In early 2020, one of teacher education program in Bangkalan, Indonesia implemented~~This led to the application of online learning through WhatsApp Group (WAG~~). However, the learning result showed that~~) in early 2020 in one of the teacher education programs in Bangkalan, Indonesia. It was discovered that 75% of preservice ~~teacher~~teachers in the program were ~~not being~~unable to complete ~~in~~their elementary linear algebra material~~. Online~~ and this led to the proposal of online learning through an asynchronous ~~learning by~~method which involves using e-learning ~~was one~~as a solution to solve the problem. ~~However,~~There is also the need to use a synchronous ~~learning needs to be implemented so that~~method to allow preservice ~~teacher can~~teachers to have virtual face-to-face ~~virtually~~interactions with their lecturers. ~~The purpose of~~Therefore, this study was conducted to determine the improvement in preservice teachers' learning outcomes and ~~preservice teachers'~~ responses to synchronous and asynchronous learning. The ~~research~~study design used was one group posttest-only ~~design.~~with 23 subjects ~~were~~ selected ~~by~~through clustered random sampling~~. Data~~ used as samples and the data obtained were analyzed ~~by~~using descriptive statistical analysis. ~~Results show~~The results showed that synchronous and asynchronous learning ~~can~~was able to improve ~~preservice teachers'~~the learning outcomes ~~and~~ for preservice teachers with most ~~preservice teachers gave~~observed to have provided a positive response ~~to synchronous and asynchronous learning. The~~. This means the combination of ~~synchronous and asynchronous learning by~~the two methods using e-learning is one solution ~~for~~ to improve the effectiveness of online learning during the Covid-19 pandemic. ~~Higher~~It is recommended that higher education institutions provide innovative e-learning platforms ~~and~~ with lecturers encouraged ~~lecturers to not only used synchronous learning in teaching but also~~ to combine ~~it with~~both synchronous and asynchronous learning ~~by using~~methods through the application of e-learning platforms.

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

Abstract. *Proses pembelajaran berubah dari tatap muka menjadi fullonline, sejak pandemic covid-19 di akhir tahun 2019. Di awal tahun 2020, salah satu perguruan tinggi keguruan di Bangkalan, Indonesia melaksanakan pembelajaran daring melalui WhatsApp Group (WAG). Namun pembelajaran ini mengakibatkan 75% mahasiswa calon guru tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui asynchronous learning dengan memanfaatkan e-learning menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, synchronous learning perlu diterapkan agar mahasiswa calon guru dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa calon guru dan respon mahasiswa calon guru terhadap synchronous and asynchronous learning. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa calon guru yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa synchronous dan asynchronous learning dapat meningkatkan hasil belajar mahasiswa calon guru dan sebagian besar mahasiswa calon guru memberikan respon positif terhadap pembelajaran synchronous dan asynchronous learning. Kombinasi synchronous dan asynchronous learning adalah salah satu solusi untuk pembelajaran daring selama pandemic Covid-19. Perguruan tinggi menyediakan platform e-learning yang inovatif dan mendorong dosen tidak hanya menggunakan synchronous*

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learning dalam mengajar tetapi juga mengkombinasikan dengan asynchronous learning melalui e-learning.

***Keywords**: Synchronous learning, asynchronous learning, e-learning, mahasiswa calon guru, aljabar linear elementer*

Introduction

~~At the end of 2019, Word was shaken by emerging~~The emergence of a new coronavirus called Novel Corona Virus (2019-nCoV~~). This~~) at the end of 2019 shook the world. The virus was originally discovered in Wuhan China in December 2019~~. A very significant~~ and later spread significantly to all countries ~~in the world occurred in early 2020~~, including Indonesia~~. This was the cause of the covid-19~~, in early 2020. The pandemic ~~in Indonesia.~~

~~The covid-19 pandemic in Indonesia~~ had a big impact ~~in various fields, ranging from Health, Economy, and Education fields. In education fields, educational's~~ on different sectors of the country including health, economy, and education. This is observed from the fact that educational institutions ranging from ~~Kindergarten~~kindergarten to ~~Universities didn't implement~~ universities were restricted from using face-to-face learning in order to reduce personal contact. ~~Furthermore~~Moreover, Azhari & Fajri (2020) ~~stated~~also showed that ~~to avoid the spread of Covid 19,~~ the government ~~gave the policy to close~~enforced policies directed toward closing classrooms without stopping learning~~, so that schools implemented~~ activities, thereby leading to the implementation of distance learning~~. Since 2020, learning had changed~~ by schools. This led to the transition from face-to-face ~~learning~~ to online learning ~~by using~~methods through the use of different information ~~technology~~technologies (Rehman & Fatima, 2021).

~~In early 2020,~~WhatsApp Group (WAG) online learning was implemented at STKIP PGRI Bangkalan ~~through WhatsApp Group (WAG). However, learning through WAG had many~~ in early 2020 but this method was observed to have several shortcomings, ~~especially in an~~specifically in the process of teaching elementary linear algebra~~ course. Based on learning outcomes data, it showed that~~. It was discovered that 75% of preservice ~~teacher didn't~~ teachers were unable to complete ~~studying. This means that 20% of preservice teacher had~~ their study while only 20% completed~~ studying~~. This ~~learning outcome had decreased significantly compared~~is considered to ~~results of~~be a significant reduction in comparison with the 86% who completed their studies as reported in previous studies ~~regarding~~conducted on the effectiveness

of learning in an elementary linear algebra course~~, which showed that 86% of students had completed their studies~~ (Sari, 2016).

~~Whereas elementary~~Elementary linear algebra ~~course~~ is a basic course ~~that must~~required to be ~~mastered~~passed by students because ~~elementary linear algebra course~~ it is a prerequisite ~~course~~ for ~~studying~~ further courses such as abstract algebra. ~~This is under the opinion of~~ Suryaningsih (2016) & Ruswana (2019) ~~who stated~~also showed that ~~elementary linear algebra was~~it is a basic subject ~~that must~~needed to be mastered by low-level students~~. If students can master material of elementary linear algebra, then students can easily learn~~ due to its ability to make learning other subjects easier.

~~Based on the explanation above,~~ This background information shows that there is a need to change the online learning ~~needs to be changed. It~~ approach. This can be ~~implemented by using~~ achieved through the implementation of asynchronous learning~~.~~ which was explained by Skylar (2009) ~~stated that Asynchronous courses provide~~to be capable of providing students with a flexible and self-paced environment ~~that was self-paced with students accessing~~they need to access course content using ~~a variety of~~different tools. ~~Students were~~ This is due to the fact that students are not usually restricted to a set day~~/~~ or time for ~~communicating, and it~~ communication, but allowed ~~students~~ more time to prepare a response to a set of directions or questions. Asynchronous learning is usually implemented ~~by using the~~through a university's e-learning ~~with moodle~~Moodle platform. ~~According to~~Meanwhile, e-learning is defined by Hambrecht (in Ogbonna, Ibezim & Obi, 2019) ~~e-learning was defined as~~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. ~~E-learning~~It normally contains the content for one semester ~~are~~such as the materials, discussion forums, and assignments~~.~~ and its use has been reported by Yuhasriyati et.al (2020) ~~stated that~~to have the ~~use of e-learning may~~ability to force educational processes to run faster in terms of accessibility and quality. ~~The use of e-learning was~~ It is also very influential on the learning activities and ~~students' learning~~ outcomes for students (Fitriani & Nurjannah, 2019~~). Furthermore, Lin, Tseng & Chiang (2017) explained that students gave~~) with the application of blended learning through Moodle platform reported to have received positive feedback ~~on the use of Moodle learning platform for~~ from students studying mathematics ~~after experiencing blended learning.~~(Lin, Tseng & Chiang, 2017).

~~Before pandemic, e-learning can be implemented in blended learning, namely combining online learning through e-learning with~~Blended learning which involves the combination of e-learning and direct face-to-face learning ~~directly. There were~~ is the norm before the pandemic and this method has been reported in several studies ~~had shown that blended learning showed~~

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~~significant success in~~ to have the ability of improving students' learning outcomes. ~~As research results by~~For example, Lin, Tseng & Chiang (2017) ~~stated that~~conducted ANCOVA and MANCOVA analyses and showed that blended learning ~~experience~~ benefitted students in the experimental group by having a positive effect ~~not only~~ on their learning outcomes ~~but also on their~~and attitudes toward studying mathematics in a blended environment. These results are in line with ~~the research of~~ Sukma & Priatna (2020) ~~which explained~~ that the implementation of blended learning ~~in Mathematics had the potential~~was able to improve ~~student's~~students' critical thinking skills (CTS).

~~However, during this pandemic learning was implemented~~Learning activities were conducted fully online during the pandemic (Trenholm & Peschke, 2020~~), which means that learning was implemented using~~) and this indicates the use of e-learning without face-to-face ~~directly. Therefore,~~ interaction. This means synchronous learning ~~was~~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) ~~stated that in real-time synchronous courses,~~ that the instructor leads the learning~~, and~~ while all learners ~~were logged on~~ log in simultaneously and ~~communicated~~communicate directly with each other in real-time.

~~Synchronous learning at~~ STKIP PGRI Bangkalan ~~was~~ implemented ~~by using zoom application, google meet application, etc. The aims of~~ synchronous learning through Zoom, Google Meet, and others to ensure students ~~could~~ understand ~~the material so that student's~~ learning materials effectively and produce adequate outcomes ~~were good~~. This is in line with the ~~research results~~findings of Aisyah and Sari (2021) ~~which stated~~ that the use of the Google ~~meet~~Meet platform ~~could~~was able to improve ~~students'~~students learning outcomes.

~~Therefore, online learning using~~This means through asynchronous learning through e-learning ~~and~~ combined with synchronous learning through the virtual conference ~~was~~is an alternative ~~in implementing~~method to teach elementary linear algebra ~~learning. Many previous research results~~in the school. Several studies showed the success of ~~asynchronous and synchronous learning. Research~~this combined method as indicated by ~~Ogbonna & Ibezim (2019) showed that synchronous and asynchronous e-learning modes increased~~its ability to increase the cognitive academic ~~achievement~~achievements of students ~~in~~studying word processing~~.~~ as reported by Ogbonna & Ibezim (2019).

~~In the middle of 2020, STKIP PGRI Bangkalan took~~ The college also implemented a policy considered to be related to online learning ~~implemented in 2 ways, namely~~ in the middle of 2020, which in the form of asynchronous and synchronous ~~learning~~. However, the synchronous learning was ~~implemented between~~ applied for 7-8 meetings~~. While~~ through webinar classes such as Zoom, Google Meet, and others while asynchronous ~~learning~~ was ~~implemented in full,~~

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~~namely~~fully used for 14-16 meetings~~. Asynchronous learning was implemented in~~ through e-learning ~~classes, while synchronous learning was implemented in webinar classes (zoom, google meet, etc.).~~ platforms.

~~However, this implementation's change of online learning needs to be evaluated for its implementation. One of them was the preservice teacher's perspective because they were~~ 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 ~~of learning. Their success was the output of learning application by the lecturer. Based on this explanation, the aims of this study were 1).~~ Therefore, this study was conducted to determine the 1) improvement of preservice teachers' learning outcomes ~~through~~based on the combination of synchronous and asynchronous learning ~~by using e-learning on~~ to elementary linear algebra ~~material,~~ and 2) ~~to determine preservice teachers'~~their responses to ~~synchronous and asynchronous~~the learning ~~by using e-learning~~method.

Method

~~*Research*~~*Study Design*

~~The author~~ Treatment was applied ~~treatment~~ to the participant's group~~,~~ to determine the ~~improvement~~effect of ~~preservice teachers' learning outcomes on elementary linear algebra material and preservice teachers' responses to~~ synchronous and asynchronous learning ~~by using e-learning,~~conducted on the outcome and responses of preservice teachers. Asynchronous learning was ~~implemented~~applied in the form of e-learning classes ~~with moodle platform. Meanwhile,~~on the university Moodle while synchronous ~~learning~~ was ~~implemented~~ in the form of webinar ~~class using zoom application~~classes on Zoom.

The learning effectiveness was ~~measured using two types, namely~~determined through tests and a list of questions~~. Instruments were given to~~ presented through instruments provided to the participants after ~~learning implementation. The author applied to learn~~the treatment. It is important to note that the treatment was applied in ~~one~~a class ~~by synchronous~~ and ~~asynchronous learning by using e-learning. Therefore,~~ this ~~study was~~means this is an experimental study ~~using~~with a one-group posttest-only design.

Participants

The population ~~in this study was~~includes all 34 preservice teachers ~~of~~in the mathematics education study program at STKIP PGRI Bangkalan ~~in~~during the odd semester of the 2021/2022 academic year~~, 2021/2022, totaling 34 preservice teachers. The author took~~while a ~~sample~~total of 23 were selected as samples~~,~~ using clustered random sampling ~~so that there were 23 preservice teachers as a sample.~~technique. The sample was heterogeneous based on gender and initial

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mathematical ability. Initial math skills were taken from determined through their calculus scores in the previous semester.

Instruments

Research Study instruments were include lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of sixteen 16 meetings, with eight meetings were implemented in conducted through e-learning class and Zoom webinar class (zoom), such as 2th classes in the 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th. The eight more meetings while the remaining were implemented in through e-learning class and WhatsApp Group (WAG), such as 1th, 3th) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th. The author implemented meetings. It is important to note that 8 webinar classes because it was under campus were conducted in line with the rules that implementation of the campus in relation to synchronous learning through webinar classes was implemented 7-8 times, this was due to constraints in purchasing internet quota. In this case, The mid-test provided to students at the 8th meeting (mid- and the final test session) and at the 16th meeting (final-test session) were conducted in through e-learning class and webinar class (zoom).

The author gave mid-test and final-test at the 8th and 16th meetings. TestZoom webinar classes. The questions were developed according to the material in the lesson plan. To get a and the tests were made valid mid-test and final-test, used 3 validities, namelythrough construct validity, content validity, and face validity. Construct validity was done validities such that the construct aspect was implemented by ensuring thatthe results of mid-test and final-test actuallyboth tests were able to measure preservice teachers'the abilities of preservice teachers in elementary linear algebra and notwithout focusing on other variables. Content validity was done by reviewing and making mid-test and final testThe content aspect involved the review and development of grids. Grids that covered questions and prepared questionrelated indicators so that no indicators were missed. The mid-test and final-test grids can be seenwithout missing any as indicated in TableTables 1 and Table 2. Face for mid and final tests respectively. Meanwhile, the face validity was doneconducted by 2 (two) experts. Experts evaluated with the focus on the evaluation of the elements of for the truth concept truth, rules for writingto prepare the questions, displays for example writing symbols and mathematical formulas, punctuation marks, pictures, and language. The face validationresults showed that the average resultface validation value for the mid-test was 4.17. The face validation average result for and the final- test washad 4.33. It means that mid-test and final-test, 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				

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No	Indicators	Learning Domain C	A	P	Level	Learning Material	Question Number	Max Score
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 ~~not both~~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 ~~so that~~to ensure the system ~~of linear equations,~~ 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 ~~by~~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

~~Tabel~~Table 2. Final Test Grid (duration 90 minutes)

No	Indicators	Learning Domain C	A	P	Level	Learning Material	Question Number	Max Score
1	Given a matrix, students can determine the matrix determinant ~~by~~ using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system ~~of linear equations~~ 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 can determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that ~~three~~they are linearly independent or linearly dependent on R^3 or $M_{2,2}$	√			C3	Linearly independent	6	15

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				and linearly dependent		
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 ~~students can~~ determine the dimensions of the S subspace of $M_{2,2}$	√	C3	Basis and dimension	8	10

~~The author developed a~~A questionnaire was developed to measure the responses of preservice ~~teachers' responses~~ teachers to the combined approach. ~~To get a valid~~The validity of the questionnaire~~, used 3 validities, namely~~ was also determined through construct ~~validity~~, content ~~validity~~, and face ~~validity. Construct validity was done by~~ validities such that the construct aspect focused on ensuring ~~that~~its results ~~of questionnaire~~ actually measure ~~preservice teachers' responses to~~ the teachers' response to synchronous and asynchronous learning ~~by using e-learning. Content validity was done by~~. The content aspect also involved reviewing and making questionnaire grids~~. Grids covered~~ to cover questions and ~~prepared question~~related indicators ~~so that no indicators were missed. Aspects of the questionnaire and indicators can be seen~~without missing any as indicated in Table 3. ~~Face~~ Meanwhile, the face validity was ~~done~~conducted by ~~2 (~~two~~)~~ experts~~. Experts evaluated elements~~ through the evaluation of the concept truth elements, rules ~~for writing~~to write the questions, and displays for language. ~~The~~ The results showed that the average face validation ~~average result~~value for the questionnaire was 4.83. ~~The~~ It is important to note that the responses to the statements on the questionnaire ~~used~~were designed to be provided through a Likert scale.

Table 3. Aspects and Indicators of ~~The~~the Questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	~~Student's~~Students' knowledge of elementary linear algebra material through online learning
			~~Student's~~Students' ability to understand every elementary linear algebra material through online learning
			~~Student's~~Students' ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in ~~Asynchronous~~asynchronous and synchronous learning	~~Student's response when~~ Students' attitude while learning independently ~~learning~~ through ~~learning~~the resources in e-learning
			~~Student's responses when~~Students' attitude while responding to discussion forums
			~~Student's responses when~~Students' attitude while downloading assignments ~~in e-learning, work it,~~ solving, and ~~upload~~uploading the answers in e-learning
			~~Student's responses~~Students' attitudes about taking synchronous learning
			Student ~~responses when~~attitude while discussing through webinar classes
			Frequency of students accessing e-learning

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3.	E-learning and Webinar classes applications	Ease of access and usefulness for students	Ease of accessing the e-learning ~~class application~~platform
			Ease of accessing the webinar class ~~application~~platform
			The usefulness of accessing the e-learning ~~class application~~platform
			The usefulness of accessing ~~e-learning~~the webinar class ~~application~~platform

The Procedure ~~of~~for Data Collection

Data ~~collection was done by giving~~ were collected using tests and ~~questionnaire. The instrument was given~~questionnaires provided online ~~by using~~through e-learning and ~~google~~Google form. ~~Learning implementation by using asynchronous and synchronous~~Meanwhile, the learning was implemented asynchronously and synchronously as indicated in ~~line with~~the lesson plan design.

Data Analysis

Data ~~analysis in this study used~~ were analyzed using descriptive statistical analysis because the aim was ~~to~~not to generate data but explain and provide an overview of the characteristics of a data series ~~of data, without doing any generation. After the test result data and preservice teacher's response data were collected, authors analyzed data~~. The processes involved are stated as follows:

1. Analysis of test ~~result~~ data

   ~~Data analysis of~~The data from the test ~~results was~~were measured using a completeness test~~.~~ ~~This completeness test consists of an~~ which includes individual ~~completeness test~~ and ~~a~~ classical ~~completeness test. The~~. Meanwhile, the Ministry of Education and Culture categorizes subjects' scores into 5 ~~categories~~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

   ~~Furthermore,~~ Widoyoko (2009) ~~determines~~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

   ~~Based on~~This information was used to establish the criteria ~~above, the author established criteria~~ for individual completeness~~, namely that~~ by setting a score of 65% as the threshold for the completion of learning by preservice teachers ~~were said to have completed learning~~

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~~if they got a score of 65% of the total score. While~~, while the classical completeness ~~criteria were~~ criterion is when 80% ~~of preservice teachers~~ have completed their studies. ~~Improved~~Moreover, improved learning outcomes were believed to be achieved if ~~preservice teachers' learning~~ the obtained outcomes are higher after the mid-test ~~were higher~~ than ~~preservice teachers' learning outcomes~~ before ~~being given~~the treatment~~. Then preservice teachers' learning outcomes of~~ was provided, as well as those in the final~~-~~ test ~~were~~are higher than ~~preservice teachers' learning outcomes of~~ the mid-test.

2. Analysis of ~~preservice teacher's~~ response data

   ~~Preservice teacher's response data obtained from~~The questionnaires ~~consists of 2 types. This was because questions from the questionnaire consist of 2 kinds, namely~~responses were classified into two, including the questions with 4 answers ~~(~~in the form of 1, 2, 3, 4~~)~~ and ~~questions~~ with 2 answers ~~(yes~~such as Yes and ~~no).~~No.

   For the first ~~question~~questions, the criteria ~~were~~are as follows:

   1, 00 ≤ average < 1, 50: less
   1, 50 ≤ average < 2, 50: enough
   2, 50 ≤ average < 3, 50: good
   3, 50 ≤ average ≤ 4, 00: very good

   ~~Preservice teachers '~~The responses were ~~said~~believed to be positive ~~if~~when they ~~were~~are in good and very good categories.

   For the second ~~question, preservice teachers'~~questions, the responses were ~~said~~believed to be effective ~~if~~when more than 50% ~~of students' responses were~~are good.

Results and Discussion

~~*The asynchronous*~~*Asynchronous and synchronous learning activities*

~~Data collection was implemented for the~~ The first ~~time~~set of data was collected on Tuesday, October 5, 2021, according to the class schedule~~. Before the first meeting began,~~ with the lecturer observed to have filled ~~out~~the required e-learning content~~. Required content, starting from~~ such as the introductory session, 1st–7th ~~sessions~~, 9th–15th ~~sessions~~, 8th ~~sessions~~, 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. ~~So, 1th~~The contents in the 1st–7th ~~sessions~~ and 9th–15th sessions ~~each contain~~include 1) greetings and ~~explanation sessions~~explanations, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, and 6) links to webinar class meetings~~. So,~~ while the 8th ~~sessions~~ and 16th sessions ~~contain~~were 1) greetings and explanations sessions~~,~~ and 2) mid-test ~~questions~~ or final-test questions according to the specified format. The display of the e-learning ~~can be seen~~platform is presented in Figures 1, 2, and 3, the discussion and closing sessions ~~can be seen~~are

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indicated in ~~Figure~~Figures 4 and 5, and the discussion sessions ~~in~~conducted on WAG ~~can be seen in~~ Figure 6.

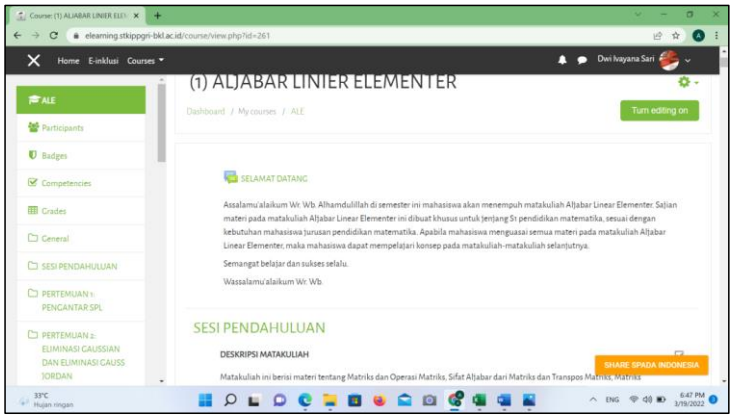

Figure 1. Front View of Elementary Linear Algebra in E-learning

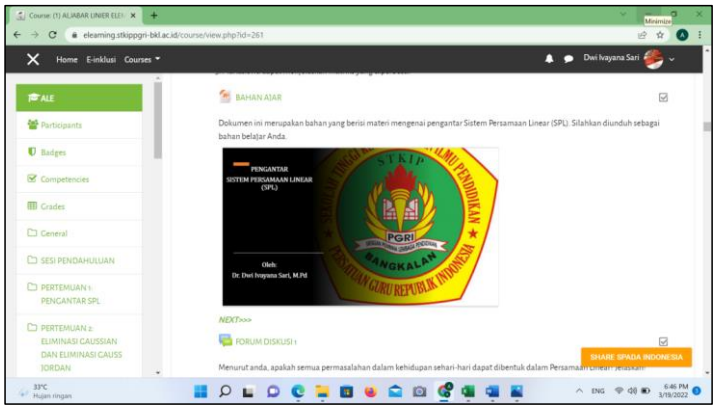

Figure 2. Content Display at ~~1~~th1st Meeting in E-learning

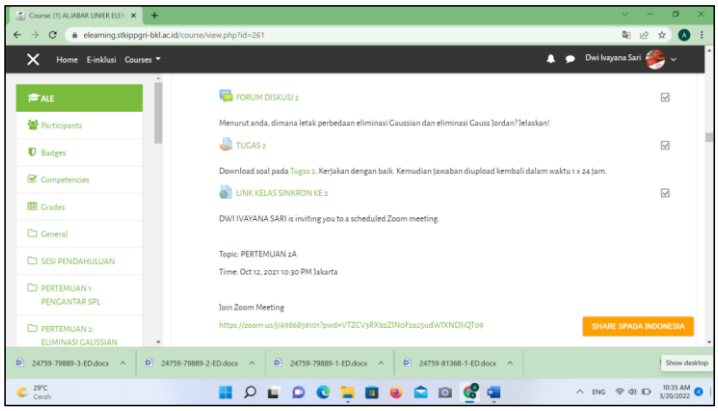

Figure 3. Content Display at ~~2th~~2nd Meeting in E-learning

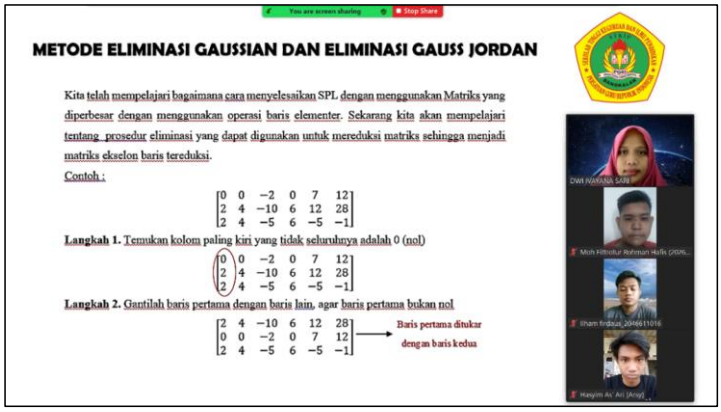

Figure 4. Discussion Session in The Webinar Class (Zoom)

Figure 5. Closing Session in ~~The~~the Webinar Class (Zoom)

Figure 6. Discussion Session in WAG

The first meeting was conducted ~~in asynchronous learning~~ asynchronously through e-learning classes~~. Preservice~~ with preservice teachers observed to have filled ~~out~~the attendance lists, accessed ~~content in e-learning~~contents, studied teaching materials, responded to discussion forums, did assignments, and uploaded answers ~~in~~to the e-learning~~. Synchronous~~ platform. Meanwhile, synchronous learning was ~~done~~conducted through WAG~~. This was done if preservice teachers didn't~~ to provide teachers the opportunities to ask questions on the parts they did not understand ~~and needed to ask. The duration of the meeting was~~from 10.30 - 13.00.

The second meeting was implemented ~~in synchronous learning~~ synchronously through a webinar class using the ~~zoom~~Zoom application~~. Preservice teacher attendance was done by filling out~~ and preservice teachers filled the attendance list in e-learning~~. The lecturer~~ after which lecturers explained the material ~~in~~using PowerPoint and video. ~~Preservice teachers could~~ They were allowed to ask questions and answer directly ~~and then discussed this through this zoom~~ followed by discussions on the application. The activity was continued ~~with asynchronous learning in~~asynchronously through the e-learning ~~class,~~platform where ~~preservice teachers~~ they downloaded tasks ~~in~~ and uploaded answers. These learning activities were continued in the 4th, 5th, 6th, and 7th meetings and followed by a mid-test conducted synchronously through a webinar class in the 8th meeting after the questions have been previously downloaded from the e-learning platform.

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

Learning ~~continued until the fourth, fifth, sixth, seventh meetings. Next, at the 8th meeting, students worked on mid-test questions through synchronous learning in webinar class. Previously,~~ *outcomes and their improvement for preservice teachers* ~~downloaded questions in e-learning.~~

~~Data collection continued until the fifteenth meeting. The learning implementation on the ninth to fifteenth meetings was implemented synchronously anf asynchronously like previous meetings. At the 16th meeting, preservice teachers worked on final test questions through synchronous learning in webinar class. Previously, preservice teachers downloaded questions in e-learning.~~

~~*The preservice teacher's learning outcomes and improvement of learning outcomes*~~

The mid-test ~~result~~results showed that 17 out of 23 preservice teachers ~~achieved scores of~~ had more than 65% of the total score. This ~~showed that~~means 87% ~~of preservice teachers~~ completed ~~studying. This showed that there was~~the study, indicating an improvement ~~of preservice teachers'~~in the learning outcomes ~~in~~of elementary linear algebra ~~material~~ after ~~online learning~~it was taught through the combination of synchronous and asynchronous learning ~~by using e-learning was implemented~~ compared to ~~preservice teachers' learning outcomes~~the period it was conducted through ~~just~~only WAG. ~~While results of~~Moreover, the final test results showed that all preservice teachers achieved ~~a score of~~ more than 65% of the total score~~. This~~ and this further confirms the improvement in the learning outcome compared to the use of only WAG as indicated by the increase compared to the mid-test results.

These findings showed that ~~100%~~ the learning outcomes of preservice teachers ~~have completed studying. This showed that there was an improvement of preservice teachers' learning outcomes~~ in elementary linear algebra ~~material after online learning through synchronous and asynchronous learning by using e-learning was implemented compared to preservice teachers' learning outcomes through just WAG. Furthermore, final test results had~~ increased ~~compared~~due to ~~mid-test results.~~

~~Based on~~ the ~~results~~application of the ~~research above, it showed that preservice teachers' learning outcomes in elementary linear algebra material through synchronous and asynchronous learning by using approaches had increased. The results of this study were~~combined method. This is in line with the results of Zaharah, Kirilova & ~~Windarti's~~Windarti (2020) ~~research which stated~~ that ~~learning using~~the application of e-learning ~~brings~~introduced progress and innovation to education in Indonesia ~~because~~ as indicated by almost 75% of students ~~conducted~~ who participated in online learning simultaneously during the ~~covid~~Covid-19 ~~epidemic.~~pandemic. Moreover, Sindu & Paramartha (2018) ~~argued~~showed that ~~theoretically,~~ the use of instructional media ~~based on~~such as video and slide synchronization ~~system~~systems theoretically facilitated ~~students at~~ the ~~time of~~ learning~~, that is, at the time of~~ ability of students during material discussion and ~~it~~also made the ~~use of~~ instructional time more effective. This ~~shows that~~means the combination of synchronous and asynchronous learning ~~by using~~

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~~e-learning~~ is one of the solutions for the challenges observed in online learning activities during the ~~Covid-19~~ pandemic.

~~*The preservice teacher's*~~*Preservice teachers' responses*

~~After all, learning was implemented, preservice~~Preservice teachers were asked to fill out a ~~subject's response~~ questionnaire ~~to online learning through through synchronous~~after the class and ~~asynchronous learning by using e-learning in elementary linear algebra material. The subject's response questionnaire could be accessed by~~the responses are made available on google ~~form~~Forms in the link https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN. ~~The~~ while the results ~~of preservice teachers' responses~~related to the knowledge aspect ~~can be seen~~are presented in the following Table 4.

Table 4. ~~The Results of Preservice Teachers'~~ Responses to ~~The~~the Knowledge Aspect

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	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

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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 set 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

Based on analysis The results ofshowed that preservice teacher'steachers' responses on knowledge aspect, it showed that (1) preservice teacher'sthe knowledge of elementary linear algebra material was good category, because preservice teacher's average respon was 3, (2) preservice teacher's as well as the ability to (2) explain the meaning of linear equation system was good category, because preservice teacher's average respon was 3, (3) preservice teacher's ability in explaining , (3) explain Gauss Jordan Elimination method was good category, because preservice teacher's average respon was 3, (4) preservice teacher's ability to, (4) solve a system of linear equations with Gauss Jordan elimination was good category, because preservice teacher's average respon was 3, (5) preservice teacher's ability to explain the meaning of matrix was good category, because preservice teacher's average respon was 3, (6) preservice teacher's ability to determine operation result of two matrices was good category, because preservice teacher's average respon was 3, (7) preservice teacher's ability to explain the meaning of determinants was good category, because preservice teacher's average respon was 3, (8) preservice teacher's ability to determine determinant of a matrix using cofactor expansion was good category, because preservice teacher's average respon was 3, (9) preservice teacher's ability to determine determinant of a matrix using row reduction was good category, because preservice teacher's average respon was 3, (10) preservice teacher's ability to prove a set wasis a vector space was good category, because preservice teacher's average respon was 3, (11) preservice teacher's ability to prove that a set wasis a subspace of another set was good category, because preservice teacher's average respon was 3, (12) preservice teacher's ability to show that a set wasis a linear combination of other sets was good category, because preservice teacher's average respon was 3, (13) preservice teacher's ability to show that an element spans a set was good category, because preservice teacher's average respon was 3, (14) preservice teacher's ability to show show a linearly independent set or linearly dependent was good category, because preservice teacher's average respon was 3, set, and (15) preservice teacher's ability to show that a set wasis the basis and dimension of a subspace in a vector space were good category, because preservice teacher's average respon was 3. This showed that preservice teachers' response to the knowledge aspect was positive.

The result of preservice teachers' responses to the knowledge aspect supported the result of improving preservice teachers' learning outcomes all in the previous analysis. These results good

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category as indicated ~~that~~by an average score of 3 for all the indicators. This means the response of preservice teachers ~~had~~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 ~~synchronous and asynchronous~~the combined learning ~~by using e-~~system was applied. This is associated with the fact that the learning ~~was implemented. This was because the availability of teaching~~ materials ~~in~~placed on the e-learning ~~or e-learning classes was~~platforms were very helpful ~~for~~to preservice teachers ~~in understanding material~~to understand the materials before they were discussed ~~it~~ in the webinar classes. ~~Therefore,~~ This shows the process of learning mathematics ~~learning~~ would not ~~experience difficulties~~have been difficult during ~~this~~the pandemic ~~if the material presentation~~ had it been the materials were presented ~~in an~~through e-learning ~~class~~platforms. This ~~was under~~is in line with the ~~opinion~~findings of Das (2020) ~~who stated~~ that mathematics education ~~would be~~is usually easier ~~if~~when conducted through virtual ~~math~~ classrooms ~~can be presented to students through the internet. Furthermore,~~ as well as the recommendation of Noviani (2021) ~~recommended~~ that e-learning design ~~was under learning objectives~~can be used to minimize the barriers to the achievement of learning objectives.

The ~~result~~results of ~~preservice teachers'~~the responses to the attitudes aspect ~~in online learning (synchronous and asynchronous learning by using e-learning) can be seen in~~are presented in the following Table 5 ~~below~~.

Table 5. ~~The Result of Preservice Teachers'~~ Responses to the Attitudes Aspect ~~in Online Learning (Synchronous and Asynchronous Learning by Using E-learning)~~

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 ~~in~~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 ~~in e-learning~~, work ~~tasks~~on them, and upload answers ~~in~~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

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~~Based on analysis results of preservice teacher's responses on attitudes aspect, it~~ The results showed that ~~(1) preservice teacher's habits in downloading~~the habit to download teaching materials ~~in~~on the e-learning ~~were~~ platform was in a good category~~, because preservice teacher's average respon was 4, (2) preservice teacher's habits in responding~~ 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 ~~in~~on the e-learning ~~were good category because preservice teacher's average respon was 3, (3) preservice teacher's habits in downloading tasks in e-learning, work tasks and uploading answers in e-learning were good category because preservice teacher's average respon was 4, (4) preservice teacher's habits in taking webinar classes were good category because preservice teacher's average respon was 4, (5) preservice teacher's habits to~~ platform as well as actively ask questions and answer during synchronous classes were found to be in a good category ~~because preservice teacher's~~as indicated by the average ~~respon was~~score of 3. This ~~showed~~simply shows that preservice ~~teachers'~~teachers response to the attitudes aspect ~~was~~is positive.

~~Preservice teachers'~~ The attitude of preservice teachers in synchronous and asynchronous learning ~~by~~conducted using e-learning was observed to be one of the ~~factors of~~ positive ~~preservice teachers'~~factors that affected their knowledge of elementary linear algebra. ~~Preservice teachers~~ They were enthusiastic about ~~this~~the online learning~~. Preservice teachers were~~ and active ~~in online learning,~~on both ~~synchronous and asynchronous learning by using e-learning.~~platforms used. The results ~~of this study~~ were discovered to be in line with the ~~results~~findings of ~~Wijaya's research~~Wijaya (2020) ~~which resulted in there was~~ that showed a good student learning attitude towards ~~the~~ learning video~~. Students~~ because they felt ~~that learning the video was very interesting yet~~ it was effective ~~as they were able to~~in making them understand the concept being taught.

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

Table 6. ~~The Result of Preservice Teachers'~~ 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~~Zoom, Google Meet, etc.)?	4	19	23	17%	83%
3	Is LMS (e-learning) class useful for you ~~in~~during the learning process?	23	0	23	100%	0%
4	Is the webinar class (~~zoom, google meet~~Zoom, Google Meet, etc.) useful for you ~~in~~during the learning process?	23	0	23	100%	0%

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~~Based on~~ Table 6~~, showed~~ shows that 61% of preservice teachers had no difficulty in using the e-learning class ~~applications. While,~~application while 83% ~~of preservice teachers~~ had no ~~difficulty in~~problems using webinar class applications~~. This showed that preservice teachers' skills in using e-learning~~ and ~~webinar classes applications were effective. The result of preservice teachers' responses to the use of e-learning and webinar classes applications supported preservice teachers' attitudes towards online learning through synchronous and asynchronous learning by using e-learning. Preservice teachers~~ 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~~. This showed that preservice teachers were~~ and are ready to face the ~~industrial~~Industrial 4.0 period as suggested by Mairing, et. al (2021).

~~Based on Table 6,~~ The results also showed that ~~100% of~~all preservice teachers ~~responded~~agreed that e-learning and webinar classes were beneficial ~~for them. The result of preservice teachers' responses to the usefulness of e-learning and webinar classes applications also~~ and this is supported ~~preservice teachers' attitudes towards online learning through~~ 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 ~~learning by using e-learning. Preservice teachers felt that e-learning and webinar classes were very useful so they were enthusiastic and active in online learning. This was in Amiti's opinion (2020) which stated that the overall study results showed that even though there could be a preference for both~~ e-learning methods~~, both synchronous and asynchronous e-learning methods if combined right, it could help teachers and learners, have a~~ can assist teachers and students in having successful course and results~~.~~ despite the preference of students for both methods.

The ~~result~~ results of the responses of preservice ~~teachers' responses~~teachers to the frequency of ~~preservice teachers~~ accessing e-learning classes in a week ~~can be seen~~are presented in Table 7.

Table 7. ~~The result of preservice teachers' responses~~Responses to the frequency of accessing e-learning ~~class~~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) ~~class~~classes in a week?	4	4	15	23	17%	17%	65%

~~Based on~~ Table 7~~, there were~~ shows that 65% of preservice teachers accessed e-learning classes 3 times a week~~,~~ while 17% ~~of preservice teachers~~ accessed ~~e-learning classes~~ 1 ~~or~~and 2 times a week. These results indicated that they were enthusiastic and active in ~~online learning through~~ using the synchronous and asynchronous e-learning platforms as indicated by ~~using e-learning. More~~the fact that

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more than 50% ~~of preservice teachers~~ accessed ~~e-learning~~it 3 times a week. ~~It reflected that~~This means they made good use of ~~this e-learning~~ the facility to support their learning process~~. E-learning could~~ due to its ability to provide everything needed to learn. This ~~was~~is in line with the ~~opinion~~findings of Xie, Liu, Bhairma, Shim (2018) ~~who stated~~ that students preferred to use asynchronous learning because ~~they could~~it can be easily ~~access it~~accessed offline~~. In addition, the asynchronous learning model was useful~~ as well as its suitability for shy students ~~and was not used in virtual discussions through computers.~~. Raymond, Atsumbe, Okwori, and Jebba (2016) ~~recommend that higher education institutions used~~ also recommended the use of innovative e-learning platforms in higher education institutions and ~~encouraged~~promoted lecturers to ~~not only used synchronous learning in teaching but also used asynchronous learning by using e-learning.~~

~~Referring to the research results, the combination of synchronous learning~~ use both synchronous and asynchronous learning ~~by using~~in the form of e-learning ~~is~~platforms.

These findings showed that synchronous and asynchronous learning through e-learning can be combined as an alternative online learning method ~~that can be applied by lecturers in teaching~~to teach mathematics ~~material~~ during the Covid-19 pandemic. This is ~~because 1)~~associated with several reasons which include the availability of teaching materials and assignments ~~in~~on the e-learning ~~class (asynchronous learning)~~platform which is asynchronous learning and considered very helpful ~~for~~to preservice teachers in understanding ~~material~~ the materials before ~~they discussed it in~~ the discussion during the webinar class ~~(~~which is synchronous learning~~). So that, synchorous~~. Asynchronous learning ~~becomes~~makes the learning process more effective~~,~~ because ~~preservice teacher has studied material, downloaded~~it provides opportunities to study materials, download tasks, and ~~done~~upload tasks ~~in e-learning, 2)~~as well as the ease with which both e-learning and webinar ~~classes are not difficult to access or use.~~platforms can be accessed and used. Therefore, it is recommended that higher education institutions ~~used~~use innovative e-learning platforms ~~and encouraged~~while lecturers are promoted to ~~not only used~~use both synchronous ~~learning in teaching but also used~~and asynchronous learning methods (Raymond, Atsumbe, Okwori, and Jebba, 2016).

~~In~~ Teachers are considered professional in the millennial 4.0~~, teachers are said to be professional if they are able~~ when they have the ability to manage ~~class by~~their classes through virtual learning~~.~~ ~~Based on research results of~~ activities. Siregar, Solfitri & Siregar (2021) ~~stated~~showed that preservice ~~teaachers have~~ teachers already had quite a good perception of online learning while attending lectures during the ~~COVID~~Covid-19 pandemic. ~~Beside that, teachers are able to make~~Their lecturers also have the ability to formulate teaching materials and assess ~~student~~ assignments ~~by~~ online~~, so that student~~ in order to increase the learning ~~increases~~opportunity for students.

Conclusion

The results showed that the application of synchronous and asynchronous ~~learning and synchronous learning could improve preservice teachers' learning outcomes in~~ online learning. ~~It can be seen from~~ methods was able to improve the learning outcomes of preservice teachers. This was indicated by the higher classical completeness ~~studying after mid-test was higher than classical completeness studying through just WAG. This also supported by the result of classical completeness studying after the final test was higher than classical completeness studying~~recorded after the mid-test~~.~~ compared to the learning activities conducted through only WAG as well as the higher value during the final test compared to the mid-test.

The ~~questionnaire results~~questionnaires analysis showed that most of preservice teachers ~~gave a~~provided positive ~~response~~responses to ~~asynchronous and synchronous~~this combined learning. ~~Preservice teachers' response to~~ method as indicated by the knowledge ~~aspect was positive, preservice teachers'~~ and attitude ~~towards learning was positive, preservice teachers were able to~~ aspects as well as the ease of access and usefulness of the e-learning and webinars ~~classes easily, preservice teachers thought~~platforms. It was also discovered that they often access the e-learning ~~and webinar classes were very useful and helped their learning. Furthermore, preservice teachers often accessed e-learning~~platform to study materials ~~and,~~ download ~~tasks,~~and do tasks, ~~and~~as well as upload ~~tasks'~~ answers ~~in e-learning~~.

~~Referring to~~This means the ~~research results,~~combination of synchronous and asynchronous learning ~~by using e-learning~~activities is an alternative online learning method ~~that can be applied by~~for lecturers ~~in teaching~~to teach mathematics ~~material~~materials during the Covid-19 pandemic. ~~Further researchers can~~It is recommended that further studies apply ~~synchronous and asynchronous~~both learning methods through e-learning to critical thinking, creativity, communication, and collaboration (4Cs~~). And then if the pandemic is over, then the effectiveness of blended learning by combining directly face to face learning with asynchronous learning (e-learning) also needs~~) considered to be ~~researched. Research's focus can be done on 4Cs because 4 abilities are very much~~ 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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Manuscript Title

The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

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The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

Abstract. *Learning activities were changed from face-to-face to full-online due to the COVID-19 pandemic at the end of 2019. This led to the application of online learning through WhatsApp Group (WAG) in early 2020 in one of the teacher education programs in Bangkalan, Indonesia. It was discovered that 75% of preservice teachers in the program were unable to complete their elementary linear algebra material and this led to the proposal of online learning through an asynchronous method which involves using e-learning as a solution to solve the problem. There is also the need to use a synchronous method to allow preservice teachers to have 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 study design used was one group posttest-only with 23 subjects selected through clustered random sampling used as samples and the data obtained were analyzed using descriptive statistical analysis. The results showed that synchronous and asynchronous learning was able to improve the learning outcomes for preservice teachers with most observed to have provided a positive response. This means the combination of the two methods using e-learning is one solution to improve the effectiveness of online learning during the Covid-19 pandemic. It is recommended that higher education institutions provide innovative e-learning platforms with lecturers encouraged to combine both synchronous and asynchronous learning methods through the application of e-learning platforms.*

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

Abstract. *Proses pembelajaran berubah dari tatap muka menjadi fullonline, sejak pandemic covid-19 di akhir tahun 2019. Di awal tahun 2020, salah satu perguruan tinggi keguruan di Bangkalan, Indonesia melaksanakan pembelajaran daring melalui WhatsApp Group (WAG). Namun pembelajaran ini mengakibatkan 75% mahasiswa calon guru tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui asynchronous learning dengan memanfaatkan e-learning menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, synchronous learning perlu diterapkan agar mahasiswa calon guru dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa calon guru dan respon mahasiswa calon guru terhadap synchronous and asynchronous learning. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa calon guru yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil menunjukkan bahwa synchronous dan asynchronous learning dapat meningkatkan hasil belajar mahasiswa calon guru dan sebagian besar mahasiswa calon guru memberikan respon positif terhadap pembelajaran synchronous dan asynchronous learning. Kombinasi synchronous dan asynchronous learning adalah salah satu solusi untuk pembelajaran daring selama pandemic Covid-19. Perguruan tinggi menyediakan platform e-learning yang inovatif dan mendorong dosen tidak hanya menggunakan synchronous learning dalam mengajar tetapi juga mengkombinasikan dengan asynchronous learning melalui e-learning.*

Keywords*: Synchronous learning, asynchronous learning, e-learning, mahasiswa calon guru, aljabar linear elementer*

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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.

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, Ibezim & Obi, 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, Tseng & Chiang, 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, Tseng & Chiang (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 & Ibezim (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.

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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 1) improvement of preservice teachers' learning outcomes based on

the combination of synchronous and asynchronous learning to elementary linear algebra, and 2) their responses to the learning method.

Method

Study Design

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 after the treatment. 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.

Participants

The population includes all 34 preservice teachers in the mathematics education study program at STKIP PGRI 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. The sample was heterogeneous based on gender and initial mathematical ability determined through their calculus scores in the previous semester.

Instruments

Study instruments include lesson plans, e-books, modules, several learning videos, mid-test, final-test, and questionnaires. The lesson plan consists of 16 meetings with eight conducted through e-learning and Zoom webinar classes in the 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 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 8th meeting and the final test at the 16th 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

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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 can 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

The Procedure for Data Collection

Data were collected using tests and questionnaires provided online through e-learning and Google form. Meanwhile, the learning was implemented asynchronously and synchronously as indicated in the lesson plan design.

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Data Analysis

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 test data

   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. Moreover, improved learning outcomes were believed to be achieved if the obtained outcomes are higher after the mid-test than before the treatment was provided, as well as those in the final test are higher than the mid-test.

2. Analysis of students' response 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 effective when more than 50% are good.

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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.

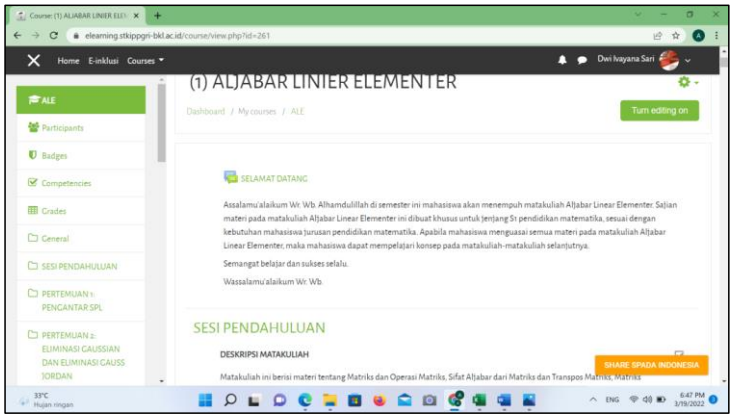

Figure 1. Front View of Elementary Linear Algebra in E-learning

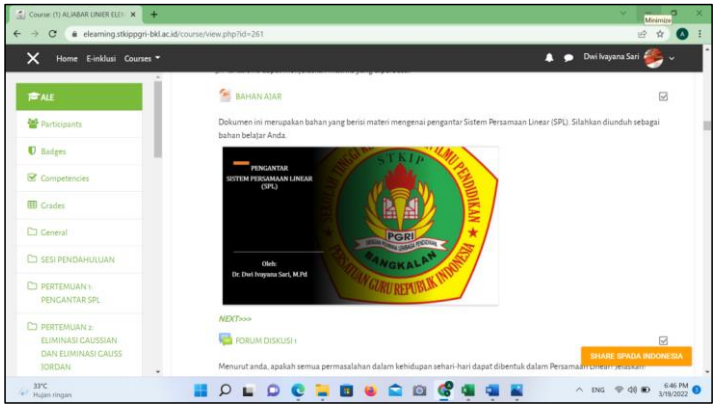

Figure 2. Content Display at 1st Meeting in E-learning

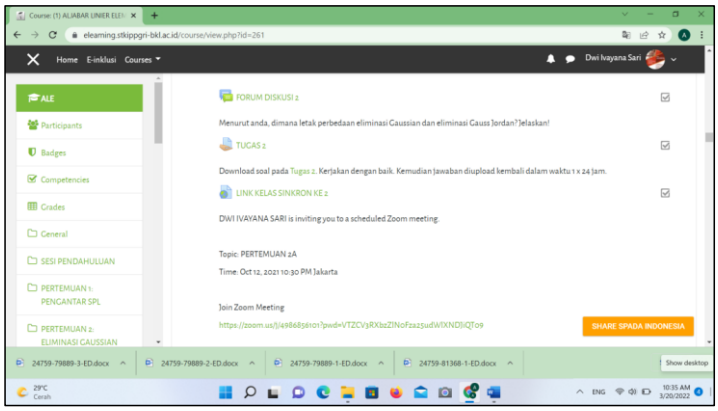

Figure 3. Content Display at 2nd Meeting in E-learning

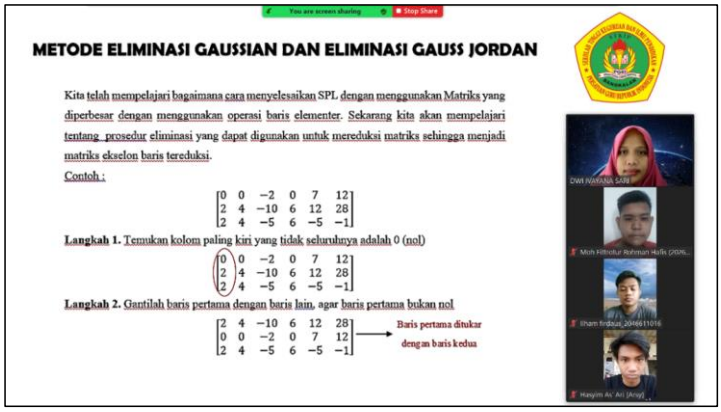

Figure 4. Discussion Session in The Webinar Class (Zoom)

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 out of 23 preservice teachers had more than 65% of the total score. This means 87% completed the study, indicating an improvement in the learning outcomes of elementary linear algebra after it was taught through the combination of synchronous and asynchronous learning compared to the period it was conducted through only WAG. Moreover, the

final test results showed that all preservice teachers achieved more than 65% of the total score and this further confirms the improvement in the learning outcome compared to the use of only WAG as indicated by the increase compared to the mid-test results.

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, Kirilova & Windarti (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 Attitudes Aspect

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 attitudes 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, Liu, Bhairma, Shim (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, Atsumbe, Okwori, and Jebba (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, Atsumbe, Okwori, and Jebba, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, Solfitri & Siregar (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. There for????? Please dicuss the implication of these findings

Conclusion

The results showed that the application of synchronous and asynchronous online learning methods was able to improve the learning outcomes of preservice teachers. This was indicated by the higher classical completeness recorded after the mid-test compared to the learning activities conducted through only WAG as well as the higher value during the final test compared to the mid-test.

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Post test and mid test are not equivalent test, it couldn't conclude improve/increse

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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HASIL REVISI BERDASARKAN HASIL REVIEW TAHAP 4

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The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

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*

Abstract. *Proses pembelajaran berubah dari tatap muka menjadi fullonline, sejak pandemic covid-19 di akhir tahun 2019. Di awal tahun 2020, salah satu perguruan tinggi keguruan di Bangkalan, Indonesia melaksanakan pembelajaran daring melalui WhatsApp Group (WAG). Namun pembelajaran ini mengakibatkan 75% mahasiswa calon guru tidak tuntas dalam belajar materi aljabar linear elementer. Pembelajaran daring melalui asynchronous learning dengan memanfaatkan e-learning menjadi salah satu solusi dalam mengatasi masalah. Namun demikian, synchronous learning perlu diterapkan agar mahasiswa calon guru dapat melakukan tatap muka secara virtual dengan dosen. Tujuan penelitian adalah untuk mengetahui peningkatan hasil belajar mahasiswa calon guru dan respon mahasiswa calon guru terhadap synchronous and asynchronous learning. Desain penelitian menggunakan one group posttest only design. Subjek adalah 23 mahasiswa calon guru yang dipilih secara clustered random sampling. Data dianalisis dengan analisis statistik deskriptif. Hasil penelitian menunjukkan bahwa hasil belajar setelah pembelajaran sinkron dan asinkron efektif dan sebagian besar mahasiswa calon guru memberikan respon positif. Kombinasi synchronous dan asynchronous learning adalah salah satu solusi untuk pembelajaran daring selama pandemic Covid-19. Perguruan tinggi menyediakan platform e-learning yang inovatif dan mendorong dosen tidak hanya menggunakan synchronous learning dalam mengajar tetapi juga mengkombinasikan dengan asynchronous learning melalui e-learning.*

Keywords*: Synchronous learning, asynchronous learning, e-learning, mahasiswa calon guru, aljabar linear elementer*

Introduction

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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.

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, Ibezim & Obi, 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, Tseng & Chiang, 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, Tseng & Chiang (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 & Ibezim (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, Sidabutar, Lada & Aritonang (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 1) improvement of preservice teachers' learning outcomes based on the combination of synchronous and asynchronous learning to elementary linear algebra, and 2) their responses to the learning method.

Method

Study Design

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.

Participants

The population includes all 34 preservice teachers in the mathematics education study program at STKIP PGRI Bangkalan 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.

Instruments

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 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 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 8th meeting and the final test at the 16th 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

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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 can 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	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

classes applications	The usefulness of accessing the webinar class platform

The Procedure for Data Collection

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.

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Data Analysis

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

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   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.

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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 ≤ average < 3, 50: good
3, 50 ≤ average ≤ 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.

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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.

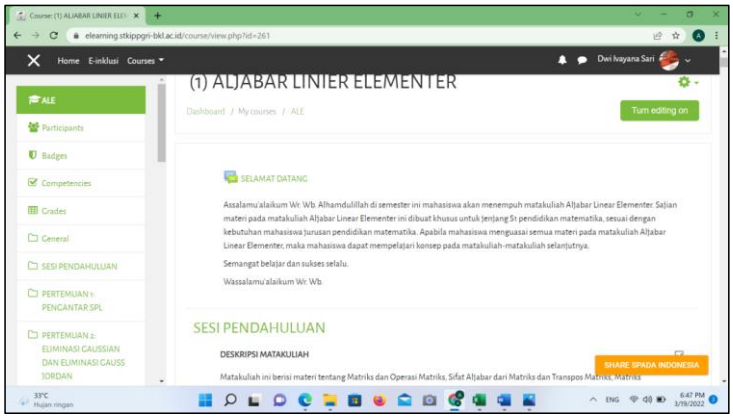

Figure 1. Front View of Elementary Linear Algebra in E-learning

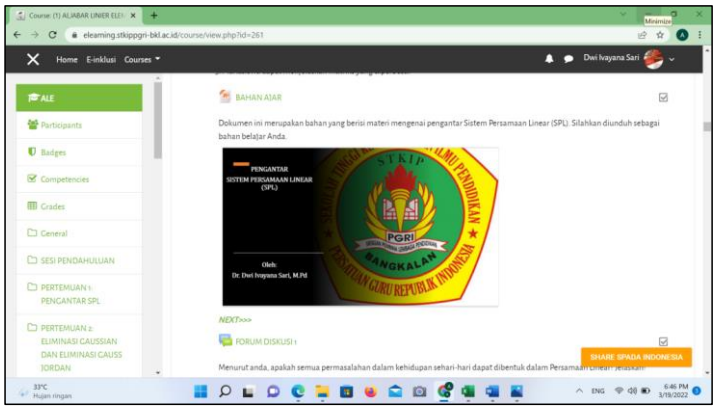

Figure 2. Content Display at 1st Meeting in E-learning

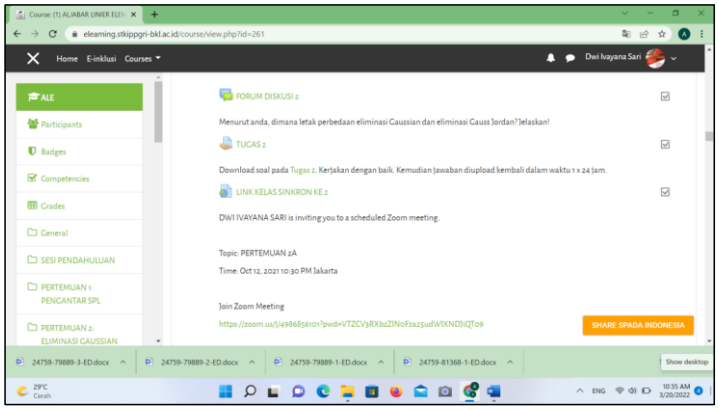

Figure 3. Content Display at 2nd Meeting in E-learning

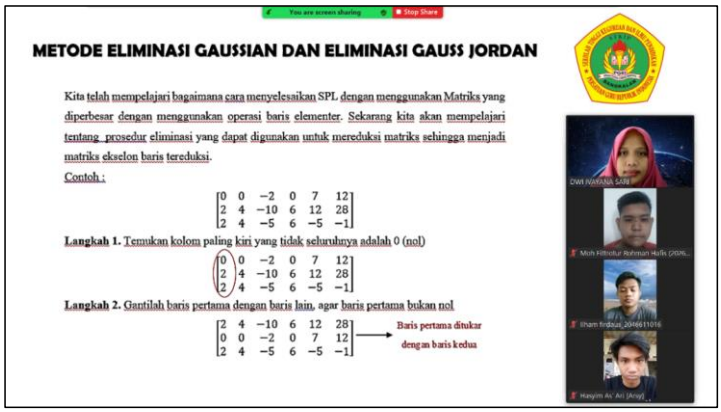

Figure 4. Discussion Session in The Webinar Class (Zoom)

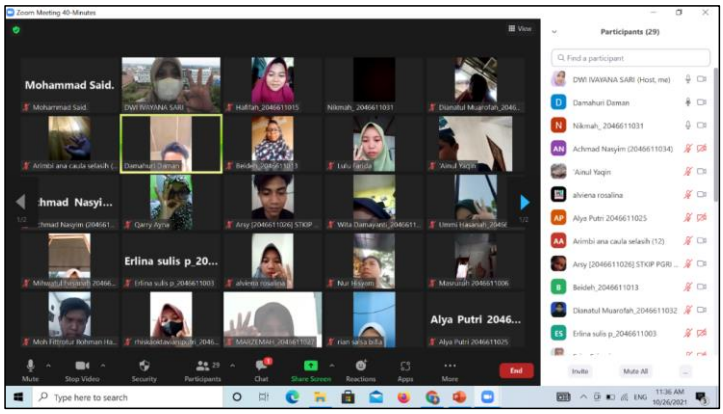

Figure 5. Closing Session in the Webinar Class (Zoom)

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 4th, 5th, 6th, and 7th meetings and followed by a mid-test conducted synchronously through a webinar class in the 8th meeting after the questions have been previously downloaded from the e-learning platform.

Data collection was continued from the 9th to 15th meetings with the learning activities observed to have been implemented synchronously and asynchronously such previous. The final test was conducted at the 16th 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.

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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, Kirilova & Windarti (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 Attitudes Aspect

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 attitudes 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, Liu, Bhairma, Shim (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, Atsumbe, Okwori, and Jebba (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, Atsumbe, Okwori, and Jebba, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, Solfitri & Siregar (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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HASIL REVIEW TAHAP 5

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The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

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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.*

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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.

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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, Ibezim & Obi, 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, Tseng & Chiang, 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, Tseng & Chiang (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 & Ibezim (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, Sidabutar, Lada & Aritonang (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.

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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 1) improvement of preservice teachers' learning outcomes based on the combination of synchronous and asynchronous learning to elementary linear algebra, and 2) their responses to the learning method.

Method

Study Design

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.

Participants

The population includes all 34 preservice teachers in the mathematics education study program at STKIP PGRI Bangkalan 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.

Instruments

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 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 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 8th meeting and the final test at the 16th 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)

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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 can 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

The Procedure for Data Collection

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.

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Data Analysis

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.

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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.

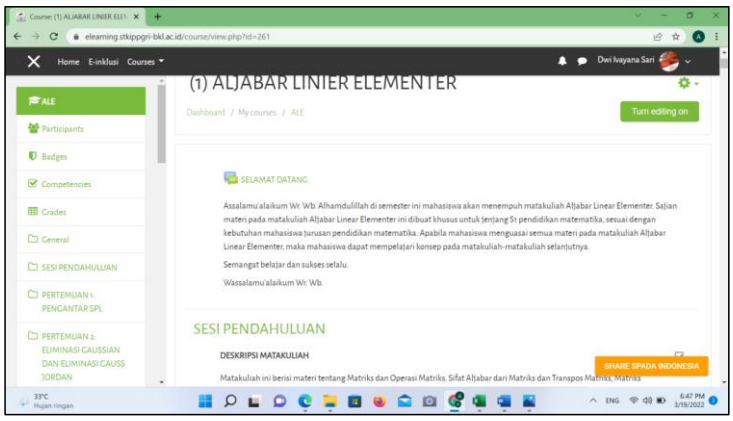

Figure 1. Front View of Elementary Linear Algebra in E-learning

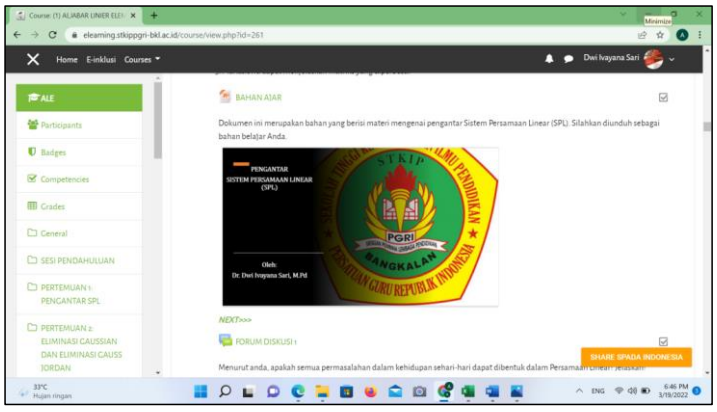

Figure 2. Content Display at 1st Meeting in E-learning

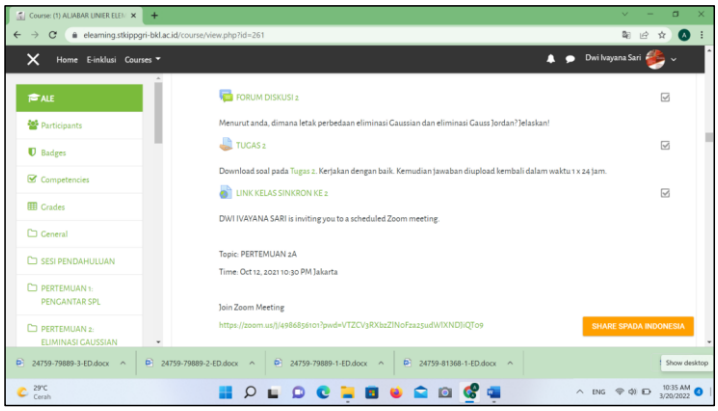

Figure 3. Content Display at 2nd Meeting in E-learning

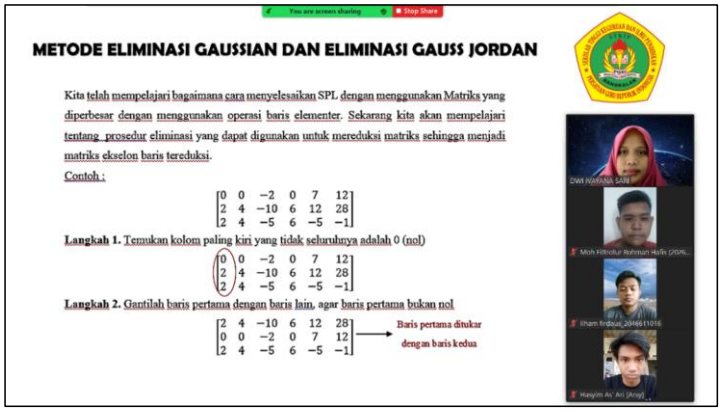

Figure 4. Discussion Session in The Webinar Class (Zoom)

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 4th, 5th, 6th, and 7th meetings and followed by a mid-test conducted synchronously through a webinar class in the 8th meeting after the questions have been previously downloaded from the e-learning platform.

Data collection was continued from the 9th to 15th meetings with the learning activities observed to have been implemented synchronously and asynchronously such previous. The final test was conducted at the 16th 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.

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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, Kirilova & Windarti (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	1	4	9	9	23	1	8	27	36	3	Good

	matrix by using row reduction											
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 Attitudes Aspect

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 attitudes 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, Liu, Bhairma, Shim (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, Atsumbe, Okwori, and Jebba (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, Atsumbe, Okwori, and Jebba, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, Solfitri & Siregar (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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HASIL REVISI BERDASARKAN HASIL REVIEW TAHAP 5

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The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

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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.*

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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.

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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, Ibezim & Obi, 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, Tseng & Chiang, 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, Tseng & Chiang (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 & Ibezim (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, Sidabutar, Lada & Aritonang (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.

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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 1) improvement of preservice teachers' learning outcomes based on the combination of synchronous and asynchronous learning to elementary linear algebra, and 2) their responses to the learning method.

Method

Study Design

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.

Participants

The population includes all 34 preservice teachers in the mathematics education study program at STKIP PGRI Bangkalan 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.

Instruments

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 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 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 8th meeting and the final test at the 16th 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.

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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 can 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

The Procedure for Data Collection

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.

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Data Analysis

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.

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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.

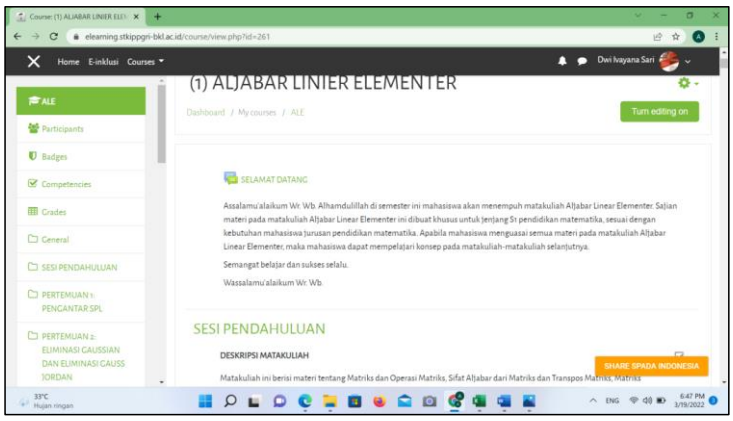

Figure 1. Front View of Elementary Linear Algebra in E-learning

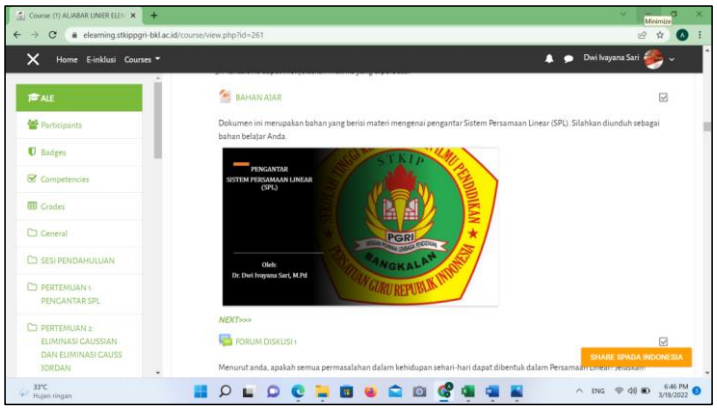

Figure 2. Content Display at 1st Meeting in E-learning

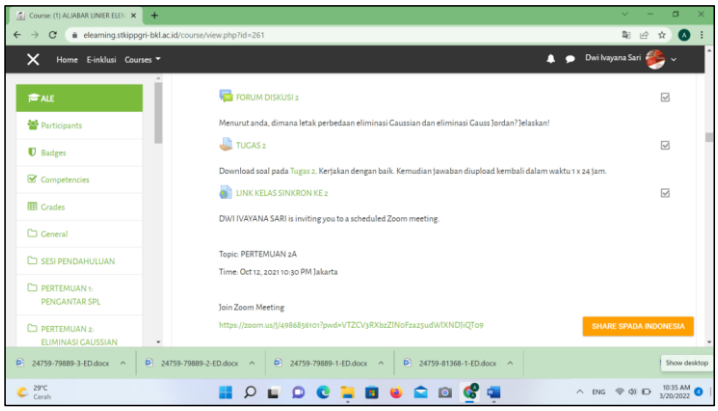

Figure 3. Content Display at 2nd Meeting in E-learning

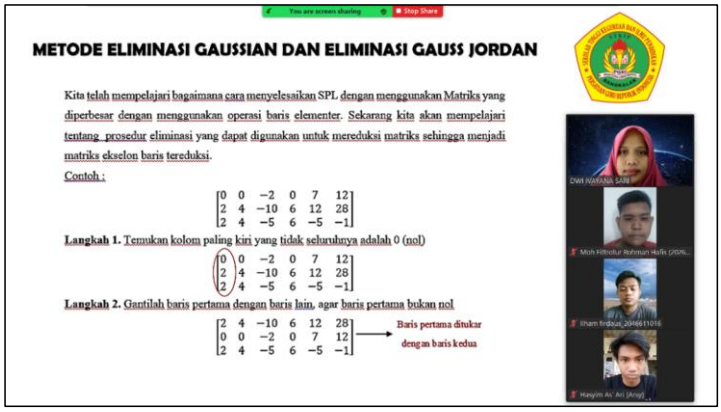

Figure 4. Discussion Session in The Webinar Class (Zoom)

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.

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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, Kirilova & Windarti (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	1	4	9	9	23	1	8	27	36	3	Good

	matrix by using row reduction											
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 Attitudes Aspect

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 attitudes 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, Liu, Bhairma, Shim (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, Atsumbe, Okwori, and Jebba (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, Atsumbe, Okwori, and Jebba, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, Solfitri & Siregar (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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HASIL REVIEW TAHAP 6

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The Application of Synchronous and Asynchronous Learning using e-Learning on Elementary Linear Algebra for Preservice Teachers

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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).

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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.

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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, Ibezim & Obi, 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, Tseng & Chiang, 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, Tseng & Chiang (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 & Ibezim (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, Sidabutar, Lada & Aritonang (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.

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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 1) improvement of preservice teachers' learning outcomes based on the combination of synchronous and asynchronous learning to elementary linear algebra, and 2) 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 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 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 8th meeting and the final test at the 16th 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.

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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 can 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

The Procedure for Data Collection

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

Commented [A12]: I have described when test and questioner were administered to the participants

learning itself was implemented asynchronously and synchronously as indicated in the lesson plan design.

Data Analysis

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

Commented [A13]: I have added mid-test and final test

Commented [A14]: I have revised by this sentence, not improve learning outcome

Commented [A15]: I have revised effective with "positive"

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.

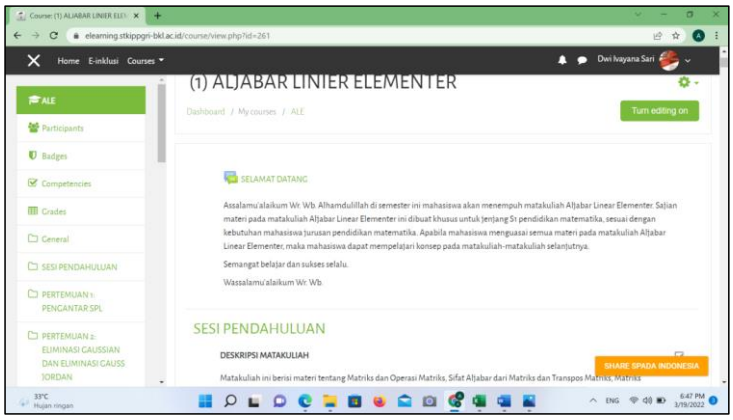

Figure 1. Front View of Elementary Linear Algebra in E-learning

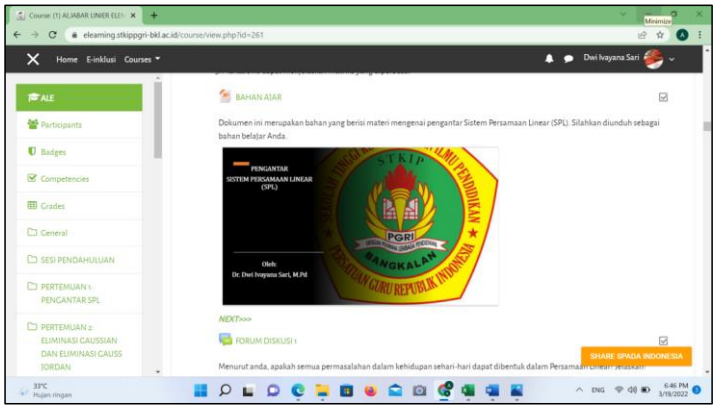

Figure 2. Content Display at 1st Meeting in E-learning

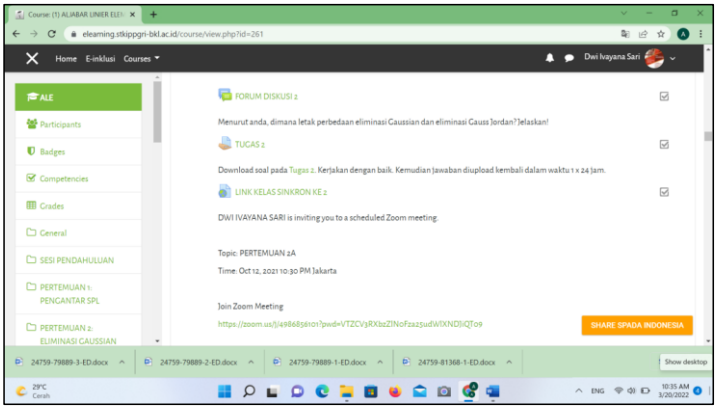

Figure 3. Content Display at 2nd Meeting in E-learning

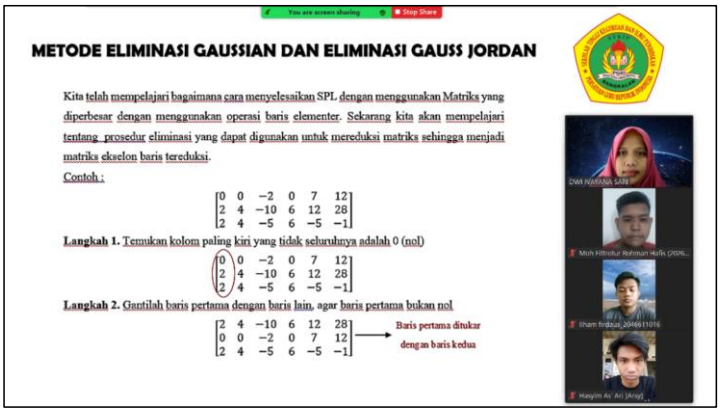

Figure 4. Discussion Session in The Webinar Class (Zoom)

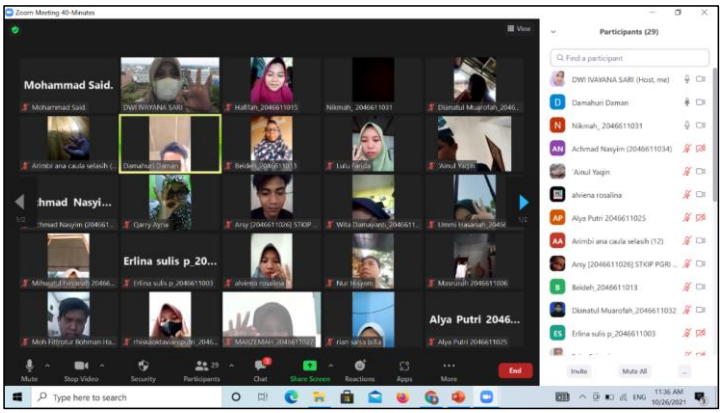

Figure 5. Closing Session in the Webinar Class (Zoom)

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.

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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, Kirilova & Windarti (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	1	4	9	9	23	1	8	27	36	3	Good

	matrix by using row reduction											
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 Attitudes Aspect

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 attitudes 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, Liu, Bhairma, Shim (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, Atsumbe, Okwori, and Jebba (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, Atsumbe, Okwori, and Jebba, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, Solfitri & Siregar (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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ARTIKEL YANG TELAH DISETUJUI SETELAH MELALUI BEBERAPA PROSES REVIEW DAN AKAN DIPUBLISH DI JURNAL DIDAKTIK MATEMATIKA

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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 can 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.

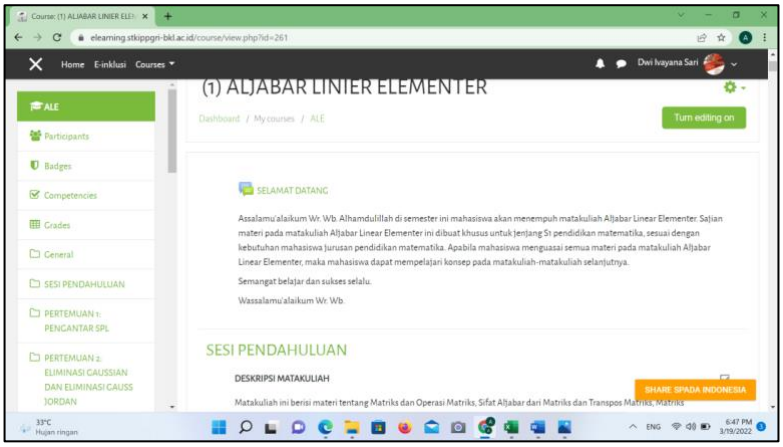

Figure 1. Front view of elementary linear algebra in e-learning

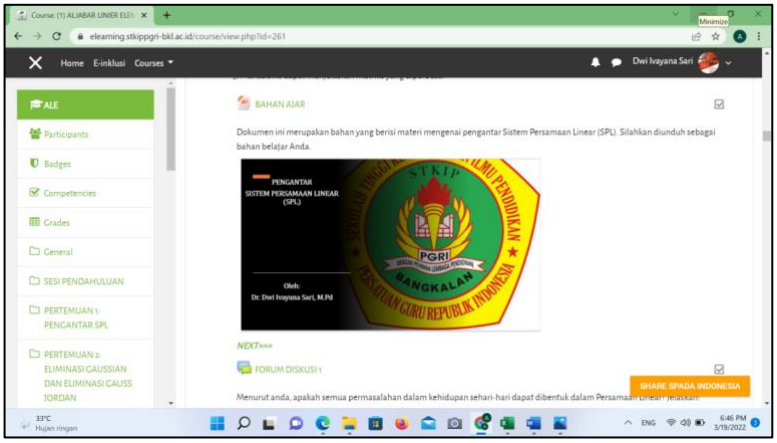

Figure 2. Content display at 1st meeting in e-learning

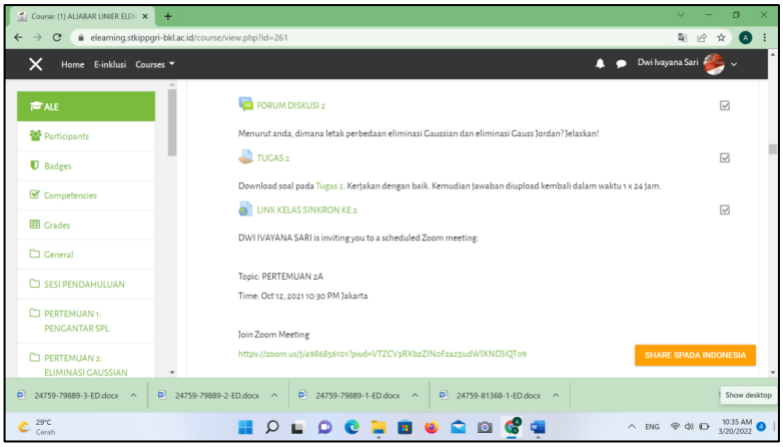

Figure 3. Content display at 2nd meeting in e-learning

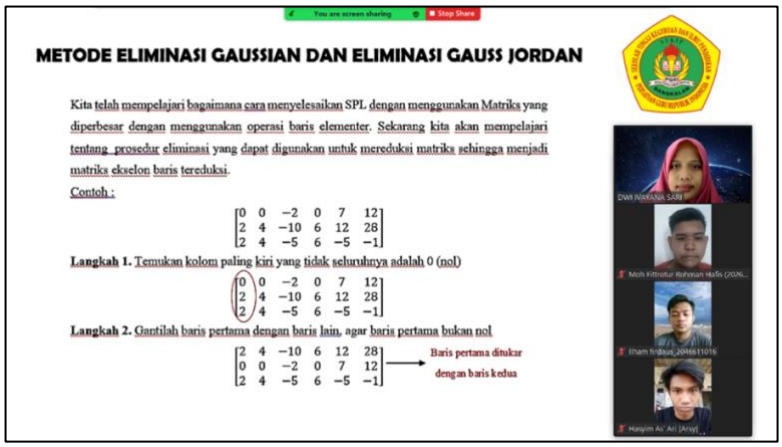

Figure 4. Discussion session in the webinar class (zoom)

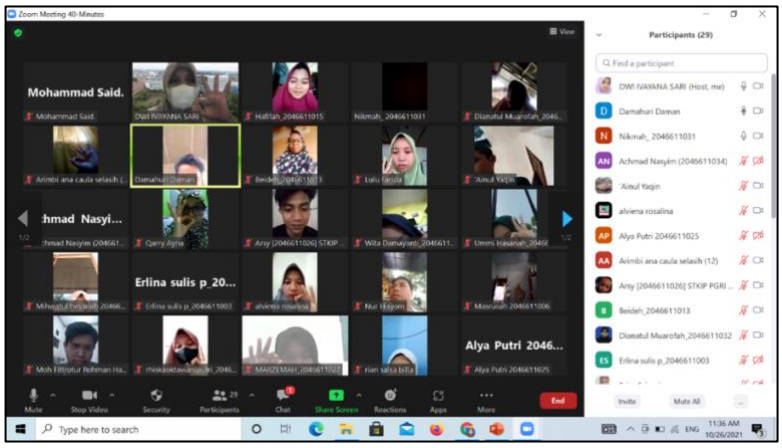

Figure 5. Closing session in the webinar class (zoom)

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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UNIT PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT (UPPM) STKIP PGRI BANGKALAN

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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.

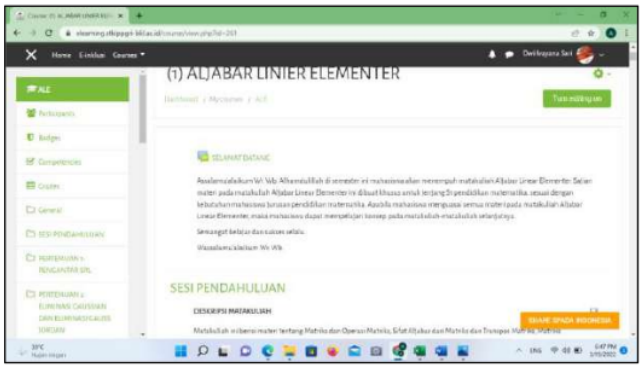

Figure 1. Front view of elementary linear algebra in e-learning

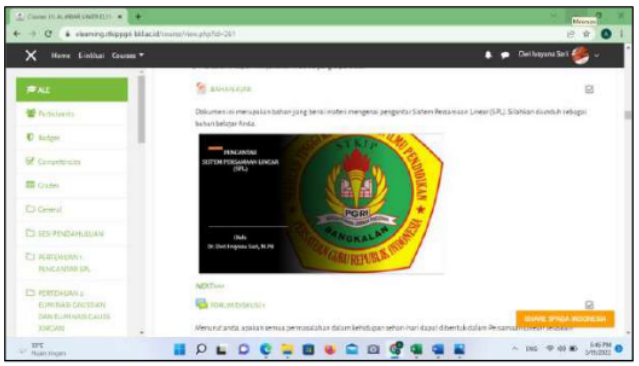
Figure 2. Content display at 1st meeting in e-learning

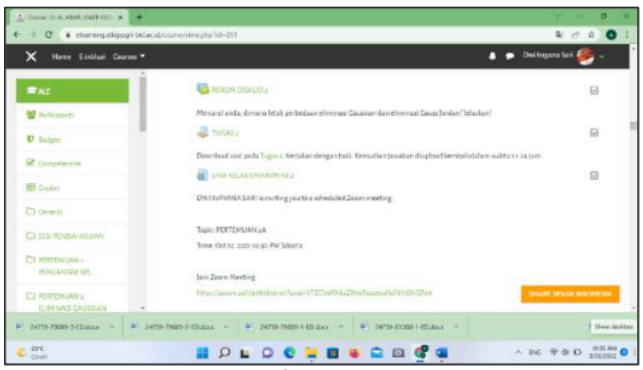
Figure 3. Content display at 2nd meeting in e-learning

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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