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DESIGNING DISTANCE LEARNING FOR GROUP THEORY COURSES TO IMPROVE THE 21ST-CENTURY PROFICIENCY OF PROSPECTIVE MATHEMATICS TEACHERS

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ABSTRACT

This study aimed to produce a distance learning design for the Group Theory course to improve the 4C skills of prospective mathematics teachers. This research is included in Research and Development (R&D), which consists of three stages, namely: (1) a preliminary study, (2) development studies, and (3) product effectiveness tests. The research results show that the distance learning design developed is feasible and effective for the learning process. Tests The research results are grouped into two parts: (1) tests for aspects of problem-solving and critical thinking skills and (2) non-tests to assess creativity and innovation, communication, and collaboration. Regarding critical thinking skills, there are differences in students' critical thinking in distance learning designs and group learning theory. However, for problem-solving skills, student problem-solving is the same as distance learning designs in group theory learning subjects. For the results of the questionnaire data analysis, it is known that the indicators for achieving creativity and innovation, communication, and collaboration are above 50%. This shows that the distance learning design of the Group Theory course has succeeded in increasing the skills of prospective 21st-century mathematics teachers.

Keywords: *Group Theory, 21st Century Proficiency, Distance Learning, Mathematics Teachers*

INTRODUCTION

The internet has made it simple to access information and disseminate expertise. This scenario is increasing learning distance globally and expanding its use in institutions of higher learning (Allen et al., 2021; Martins et al., 2021). Distance learning is an ally in teaching and learning when dealing with the coronavirus pandemic and new viruses and implementing severe World Health Organization (WHO) standards to follow social isolation measures (Martins et al., 2021; WHO, 2020). One of the activities that the COVID-19 epidemic has impacted is the field of education, notably higher education. The pandemic has changed many elements of human activity.

Universities must be able to offer distance learning services that can meet all the requirements of students who wish to pursue distance learning. In terms of human resources, technology infrastructure, and learning systems management systems, many higher institutions are not yet prepared to offer distance learning. When migrating from traditional face-to-face channels to distant learning, educational institutions must prepare, which results in several issues (Iqbal et al., 2019). Therefore, a distance learning design must be conducted to ascertain the level of user acceptance of the distance learning system (learning management system). Due to the integration of numerous technologies into the educational setting as a resource for teaching and learning in the digital era, education has sought new meaning in practice. According to Cambruzzi et al., while definitions of distance learning differ, they always consider the following factors: (1) distance learning does not take place in the exact physical location; (2) it permits students to study at different times; and (3) it uses technology to mediate. Distance learning produces data that can be used in many different sorts of analyses because of the high level of mediation (Cambruzzi et al., 2015). Using technical resources, distance learning seeks to provide a comprehensive, dynamic, and effective teaching and learning experience. It has rapidly expanded and assumed a crucial position in the educational system (Martins et al., 2021).

The problem is that not all *e-learning platforms* have an effective instructional design that can lead to a successful learning experience. Such *platforms may need help with problems such as insufficient user* interactivity, a lack of rich content, substandard structured learning content, or even wholly unstructured learning content. (Costa et al.,

2022; Dimitropoulos et al., 2022; F. Anaraki, 2004). Especially in the post-pandemic 4.0 industrial revolution era, students need a system to facilitate durable and reliable knowledge construction and retention. Many e-learning platforms and methods have emerged and tried to solve this problem, but not all with the desired success. This kind of deeper learning is much more challenging to apply effectively; it requires thoughtful, multifaceted instructional and interaction design to operate as intended and keep learners engaged (Dimitropoulos et al., 2022). Therefore, we need a distance learning environment that is flexible, accessible, collaborative, and multidisciplinary to meet the needs of aspiring teachers. Researchers have recently focused on strategies to help teachers improve professionally (Aykan & Yıldırım, 2022; Sadler et al., 2020). However, these strategies are imperfect, preventing teachers from realizing themselves professionally. Therefore, we must concentrate on the distance learning process. (Aykan & Yıldırım, 2022)

Distance education has been used in classrooms for three decades and facilitates the educational process for both teachers and students. This allows interaction between participants in the educational process (Daher et al., 2022), learning motivation (Beluce, AC; Oliveira, 2015), engagement in learning (Simonsen, M.L.; Morningstar, M.E.; Xie, 2017), and learning assessment (Amer, A.; Daher, 2019). Recently, distance learning has been rife in emergency education due to COVID-19 (Hamdan, R.; Ashour, W.; Daher, 2021). This development led researchers to consider this mode of learning broadly (Jiménez-Bucarey, C.; Acevedo-Duque, Á.; Müller-Pérez, S.; Aguilar-Gallardo, L.; Mora-Moscoso, M.; Vargas, 2021).

In Indonesia, the issuance of Freedom Regulation by the Minister of Education and Culture Number 3 of 2020 became the basis for Freedom to Learn Independent Campus Policy Number 754 of 2020 concerning 8 Higher Education Performance Indicators demanding universities in Indonesia to carry out distance learning to facilitate student learning off campus. This is done to prepare Indonesian human resources to face changes in society, culture, the world of work, and rapid technological advances so that they have linked and matched competencies and are ready to compete.

Regarding the basic concept of distance learning, learning in the 21st century is essential to implement the Merdeka Learning Program for the Independent Campus [Ministry of Education and Culture, 2020; Kristanto, 2020]. One of the competencies needed in the 4.0 revolution era is 21st-century skills, which include character quality, literacy, and competence. However, the survey results show that implementing the lecture process oriented toward developing 21st-century skills for prospective teachers in Indonesia still needs to be higher [Aryanna, 2019]. Preparing prospective teachers with these skills is currently the focus, especially for prospective teachers. Today, based on the PISA study, Indonesia has the lowest literacy skills in mathematics, science, and language. Among the causes are the quality of teachers and the quality of learning, which still needs to improve [Fitriati and Prayudi, 2020; Fitriati and Novita, 2018]. Therefore, it is necessary to prepare adaptive human resources as a form of response to these conditions. Innovation communication, 21st century, and 21st century must be possessed by prospective teachers consisting of 4C skills (critical thinking and problem-solving, creativity and innovation, communication, and collaboration).

In addition, in the Mathematics Education Study Program curriculum, group theory is a subject group included in the primary curriculum that students must take. The facts show that students still need help understanding group theory. This viewpoint material could be more satisfactory when viewed from the perspective of students' abilities in solving proof problems in group theory courses [Judge, 2017]. Several empirical studies have shown that teacher knowledge construction in abstract algebra and student achievement in school are not significantly correlated [Veith, 2022; Wasserman, 2018]. Over the past two decades, many studies have shown how studying abstract algebraic concepts affects one's view of mathematics in general. For example, with a course for mathematics teachers [Nicholas, 2014]. However, problems that are often considered difficult are assigned to challenging material, which is difficult for students partly because of the nature of group theory [Ioannou, 2017].

Therefore, researchers need to implement distance learning by developing teaching materials that collaborate between textbooks, learning videos, and online assessments, allowing students to get

feedback quickly and openly. This is an effort made to improve the skills of prospective mathematics teachers in the 21st century, focusing on student competence in solving complex problems through improving four skills, namely critical thinking, creativity, communication, and collaboration. The implementation uses the campus LMS (e-learning). E-learning can allow students to have more experiences that can be achieved because they learn from content and online communities and networks. In this way, e-learning can support "learning through reflection and discussion" [Al-Arimi, 2014].

Educators must continuously reflect on their teaching practices and apply and develop the latest learning models to create innovative, active, and in-depth learning. This is in line with Astuti's 2019 research, which states that to prepare students for the 21st century, it is necessary to have teachers who can inspire the learning process. The 21st-century generation has the characteristics of multitasking, multimedia, and online information retrieval. Creating the 21st century generation above requires several skills teachers must possess. The 21st century demands that every human being have comprehensive abilities. They must use a balanced ability between knowledge, skills, attitudes, and values in their lives (Chalkiadaki, 2018; Schleicher, 2018; Wang et al., 2018). They must utilize and handle rapidly developing information, processing, automation, and communication in everyday life (Asrizal et al., 2022; Zhong et al., 2022). Implementing learning in the 21st century must comprehensively integrate students' various abilities. Students need comprehensive knowledge, skills, and attitudes to think and act naturally (Abaniel, 2021; Ang, 2018; Malik, 2018; Ongardwanich et al., 2015). Learning must facilitate students' use of information technology in building their abilities. The challenges of the 21st century can be answered with education. 21st-century education needs to integrate knowledge, attitudes, skills, and mastery of information technology (Aabla, 2017; Afandi et al., 2019; Malik, 2018). Therefore, a prospective teacher needs to be equipped and practice distance learning. Prospective teachers must also have digital skills (knowing and mastering the digital world), thinking skills, interpersonal and communication skills (having communication skills to argue), global skills (having skills including foreign language skills and the ability to adapt to foreigners who have different cultures), and sensitivity to cultural values. The characteristics and demands of the 21st century above resulted in four characteristics of 21st-century learning, namely: (1) Critical thinking and problem solving; (2) creativity and innovation; (3) communication; and (4) collaboration.

According to Utami (2018), the 21st-century skills needed in learning are critical thinking and problem-solving, communication, collaboration, creativity, and innovation. Not much different from that, the four highest skills needed for work are creativity and innovation, analytical and problem solving, technical skills, communication, and collaboration.
Regarding this issue, the author tries to respond quickly to this condition by developing a distance learning design based on 4C skills in the Group Theory course to improve 21st century skills for prospective mathematics teachers.

METHODS

This study uses research and development (R&D) methods. The development model used in this activity is the model (Borg et al.; M.D. Gall, 2014) simplified by (2013), as shown in the following figure.

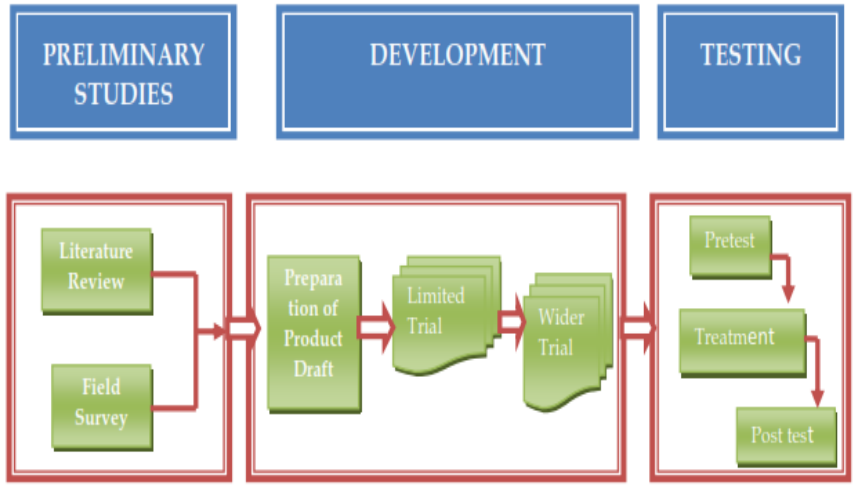


Figure 1. Research and development steps (Sukmadinata, 2013)

The initial study and development phase has been completed, and the results have been published in proceedings. For this reason, this article focuses on the third stage, namely testing. To test the effectiveness of the 4C skill-based online learning designs and tools, this study used a quasi-experimental research design in the form of a nonequivalent control group design. In this design, the experimental and control groups are not randomly selected (Sugiyono, 2016). Two groups will be given a pretest, then treatment, and a posttest, as illustrated in Figure 2.

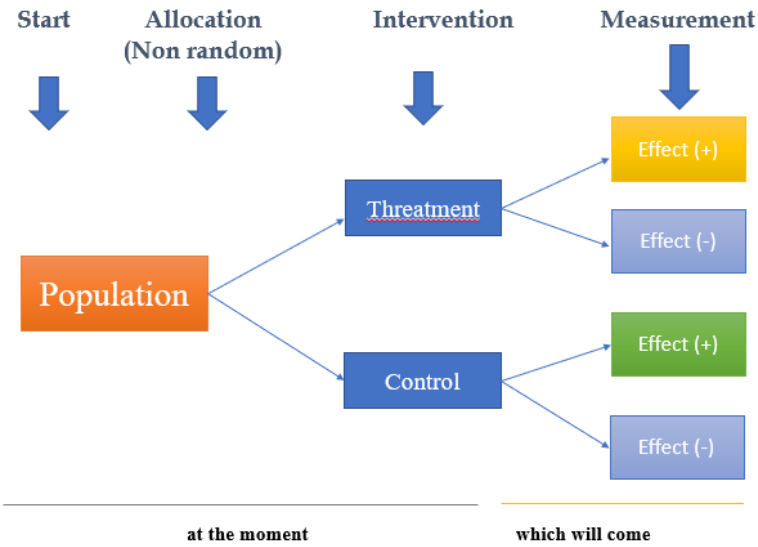


Figure 2. Experimental Research Design to be used

To analyze the development of 21st-century skills (critical thinking and problem-solving, creativity and innovation, communication, and collaboration), researchers will use an assessment rubric by adopting the attainment indicators advanced by S-Based Partnership for the 21st Century (accessed, 2009) and Rice, Cynthia (2017), as shown in Table 1.

Table 1. Assessment Indicators for four 21st Century Skills

Skills	Achievement Indicator
Critical Thinking and Problem Solving	1. Compare information from various sources before completing a task. 2. Draw your conclusions based on analyzing relevant facts or information. 3. Summarize and interpret what you have read or taught yourself. 4. Analyze arguments, perspectives, or solutions to contentious issues. 5. Build persuasive opinions based on supporting evidence and reasoning. 6. Trying to solve a complex problem or answer a question with more than one correct answer.
Creative and Innovation	1. Using an idea creation technique in the form of a concept map 2. Test various theorems to improve your skills

	3. Finding solutions to complex questions 4. Make products in the form of applications based on group questions
Communication	1. Arrange results in the form of data used for presentations 2. Convey ideas using posters and videos 3. Prepare and make presentations 4. Answer questions 5. Determine how they will describe their work and present it
Collaboration Skills	1. Work in groups to complete shared tasks 2. Work with other students to set goals and make plans for their Groups 3. Create a Joint Product 4. Presenting the results of the Group's work 5. Work as a team to incorporate feedback on Group assignments 6. Provide feedback to peers

Source: US-based Partnership for 21st Century skills [20] (S-Based Partnership for 21st Century, accessed, 2009)

This research was conducted on students of the mathematics education study program at Bina Bangsa University Getsempena. The research subjects totalled 60 students divided into two classes, namely 31 students in the control and 29 in the experimental classes.

Instruments are in the form of pretest and posttest posttest data and questionnaire data. Questionnaire distribution is used through Google Forms. Tests for problem-solving and critical thinking skills in the form of descriptive questions covering material: introduction to groups, binary operations, group definitions, group characteristics, abelian groups, regular groups, groups Cyclic, Group permutations, subgroups and group homomorphisms. Instruments in the form of non-tests are used to assess creativity and innovation, communication and collaboration in the form of an assessment rubric. The assessment indicators used are in Table 1.

Experimental data will then be processed using SPSS 20 with the Mann-Whitney U technique to see the impact of the developed design on students' 21st-century skills. The validity and reliability of data collection and analysis processes should be described sufficiently.

RESULTS AND DISCUSSION

The results of distance learning designs in Group theory courses in modules, LKM, and learning videos are suitable for use based on enthusiastic user trials and student questionnaire results, an average of 80.35% (data published in proceedings). The results of testing the effectiveness of 4C skills-based online learning designs and tools are based on the 4C skills assessment indicators. To get the effectiveness of the 4C skill-based online learning designs and tools, the researchers applied the results of distance learning designs in the learning process in the form of modules, LKM, and learning videos to students. The teaching and learning process is done online by lecturers and students through the campus LMS using synchronous and Asynchronous methods. For synchronization, lecturers use Zoom and Google Meet, which are already integrated with the campus LMS. As for Asynchronous, students use learning videos published by lecturers on YouTube and integrated into the campus LMS. Researchers gave pretest and posttest posttest to students in the form of description questions through the campus LMS with a 100-minute process. The results are categorized into two parts, namely problem-solving and critical thinking skills tests and non-test tests to assess creativity and innovation, communication, and collaboration.

The resulting group theory course sets for distance learning consist of lecture contracts, Semester Learning Plans, assessment instruments, teaching materials, Student Worksheets and learning videos. To produce these products, the following activities will be carried out : (1) Curriculum Study Program Analysis (2) LMS development by the UTI team ; (3) Development of group theory course materials along with learning videos); (4) Integration of materials into LMS; (5) Determination of the structure for implementing distance learning ; (6) Testing is limited to checking the functioning (Students and Lecturers); (7) Validation of learning tools by experts ; (8) Revisions of the program and (9) The program is ready to be implemented.

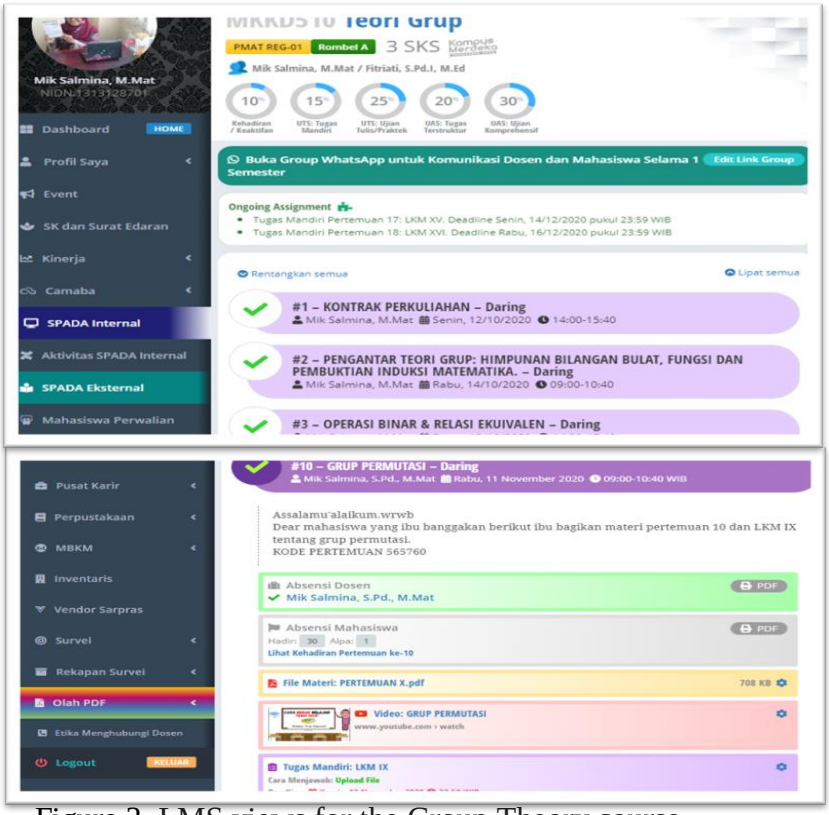
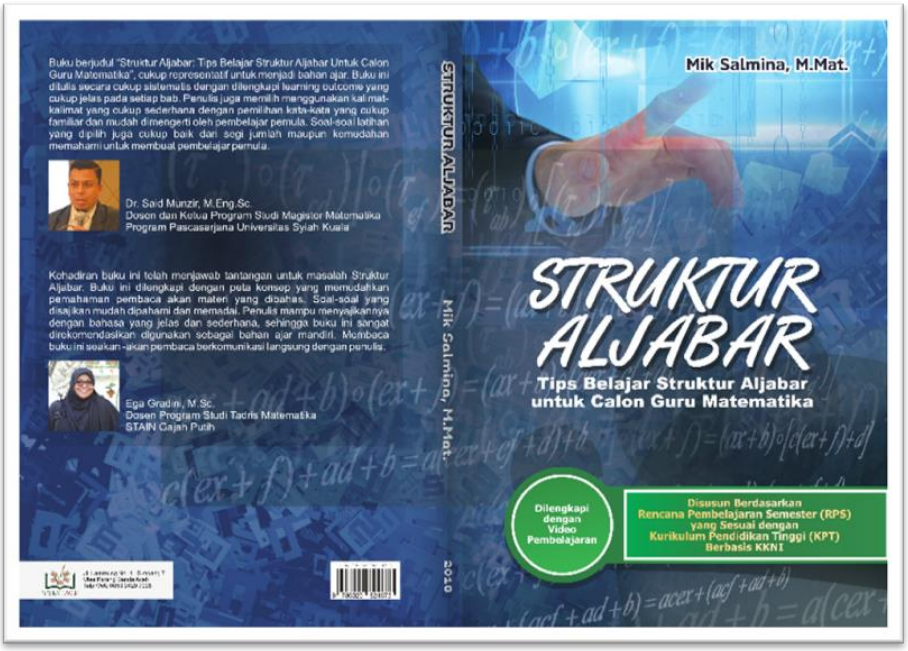


Figure 3. LMS views for the Group Theory course

The learning materials in group theory courses are developed based on predetermined learning outcomes by following the agreed rules in the Mathematics Education Study Program. The implementation of distance learning uses the campus LMS (e-learning) page with the page address www.opensimka.com/web. The following displays the LMS in group theory courses in Figure 3 and Teaching materials in Figure 4.



Figures 4. Teaching materials on group theory courses

Think Critical and Problem Solving

To see critical thinking skills and problem-solving, researchers gave a pretest and posttest post-test conducted by 60 students and divided into two classes, namely 31 students in the control class and 29 students in the experimental class.

Table 2. Non-Parametric Test Results for Critical Thinking

Test Statistics [a]	
	n-gain value
Mann-Whitney U	313,500
Wilcoxon W	809,500
Z	-2,026
Asimp. Sig. (2-tails)	043
a. Variable Grouping: class	

As for solving this problem, a homogeneity test is followed to obtain homogeneous data because the two data are typically distributed. Because the data is usually distributed and homogeneous, the hypothesis testing is continued with the t-test.

Table 3. T-test results for Troubleshooting

Independent Sample Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	Q	Df	Sig. (2-tails)	Meaningful Difference	St. Error Difference	95% Confidence Interval of Difference	
									Lower	On
n-gain value	Equal variances are assumed	.763	.386	.314	58	.755	.01909	.06076	-.10254	.14072
	Equal variances are not assumed.			.312	55,175	.756	.01909	.06109	-.10333	.14151

To see critical thinking skills and problem-solving, researchers gave a pretest and posttest post-test conducted by 60 students and divided into two

classes, namely 31 students in the control class and 29 students in the experimental class. Based on the normality test using the "Shapiro-Wilk", it is known that the n-gain control class data and the n-gain Critical Thinking ability experimental class are generally not distributed. Therefore, the hypothesis test is continued using a non-parametric test, namely the Mann-Whitney-U. From the results of the non-parametric test using the Mann Whitney-U technique, testing the students' critical thinking hypothesis shows a value with a significant level = 0.043, which means that the value is smaller than the significant level (0.05) or 0.043 <0.05, so Ha is accepted, and H0 is rejected . as presented in Table 2. The conclusion is that there are differences in improving the experimental class's critical thinking skills compared to the control class's. This means there are differences in students' critical thinking towards distance learning designs in group theory courses so that they can improve 21st century skills, namely critical thinking.

As for solving this problem, a homogeneity test is followed to obtain homogeneous data because the two data are typically distributed. Because the data is usually distributed and homogeneous, the hypothesis testing is continued with the t-test. Because the significant value is 0.755 > 0.05, as presented in Table 3, it can be concluded that there is no difference in the improvement between the problem-solving abilities of the experimental class and the problem-solving abilities of the control class. This means student problem-solving is the same as distance learning designs in Group theory courses. This is because two indicators of achievement have not been fulfilled; namely, students have not been able to analyze more deeply the problem for which a solution is to be found, and in solving complex problems, they are still based on one method and have not been able to explore deeper information from concepts related to definitions and theorem.

Creative and Innovation Skills, Communication and Collaboration

To see creative and innovative abilities, communication and collaboration, the researchers gave a questionnaire to 60 students. The results of the questionnaire obtained are presented in Table 4 below.

Table 4. Indicators of 21st Century Skills Assessment

Skills	Achievement Indicator	Average Percentage
Creative and Innovation	1. Using an idea creation technique in the form of a concept map 2. Test various theorems to improve your skills 3. Finding solutions to complex questions 4. Make products in the form of applications from group questions	66%
Communication	1. Arrange results in the form of data used for presentations 2. Convey ideas using posters and videos 3. Prepare and make presentations 4. Answer questions 5. Determine how they will describe their work and present it	78%
Collaboration Skills	1. Work in groups to complete shared tasks 2. Work with other students to set goals and make plans for their Groups 3. Create a Joint Product 4. Presenting the results of the Group's work 5. Work as a team to incorporate feedback on Group assignments 6. Provide feedback to peers	83%

To see creative and innovative abilities, communication and collaboration, the researchers gave a questionnaire to 60 students. Based on the results of Table 4, the average achievement indicators achieved by students in Group Theory courses with PJJ designs are above 50% for creativity, communication,

and collaboration. This shows that the PJJ design in the Group Theory course has been successfully applied to students of the Mathematics Education study program at Universitas Bina Bangsa Getsempena.

This is in line with the results of research conducted by (Andrini et al., 2021) regarding the enhancement of 4C competencies (Creativity, Critical Thinking, Collaboration, and Communication), and the result is an increase in 4C competencies before and after being given a distance blended learning model. Learning system. Flexibility to study anytime and anywhere through face-to-face communication and online interaction using online chat and forums to explore critical thinking through discussion (Jalinus, 2021). Besides that, the research results (Nonthamand, 2020) show that learning design models influence teaching strategies, instructor preparation, media and technology, studies cases, Group processes, and activities to share ideas. The novelty of this research is the application of distance learning using digital platforms. Web and server-based applications are cloud-based, integrated into the LMS (Learning et al.), and are named OPENSIMKA.

CONCLUSION

Based on the results and discussion in this study, it was found that distance learning design in Group theory courses can improve 21st century skills, namely critical thinking. Still, for problem-solving, there has yet to be any improvement. The questionnaire results for the type of creativity and innovation skills reached 66%, communication at 78% and collaboration at 83%. This shows that the distance learning design in the Group Theory course has succeeded in increasing the skills of 21st century mathematics teacher candidates.

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