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STEM-based E-learning: Implementation and Effect on Communication and Collaboration Skills on Wave Topic

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Abstract

Communication and collaboration are essential skills that students must master in the 21st century. These skills can be raised and improved through systematic learning, such as the STEM approach. This study aims to determine the effect of STEM-based e-learning applications on high school students' 2C (communication and collaboration) skills on wave material. This type of research was quasi-experimental, using the pretest-posttest method. The population of this study was 11th-grade students of the science program at public senior high school number 2 Palembang. Data analysis techniques used quantitative data analysis techniques to analyze the data collected from students' 2C skills achievement scores. The results of data analysis on the average pretest on communication skills got a value of 54, while collaboration skill was 55. After applying STEM-based e-learning on wave material, the average post-test scores on communication and collaboration skills were 82.7 and 85.7. It showed that the students' 2C skills increased after using STEM-based e-learning on wave material. The main finding of this study was that the application of STEM-based e-learning on wave material effectively improved students' 2C (communication and collaboration) skills. It was evidenced by the analysis results of the N-gain test, which showed that students with communication skills scored 0.62 in the medium category and 0.68 in the medium category for collaboration skills.

Keywords: STEM, e-learning, communication skills, collaboration skills

INTRODUCTION

The rapid development of technology, information, and communication is one of the main signs of entry into the globalized era or the era of the 21st century (Hermawan et al. 2017; Dewantara et al. 2020; Wiyono & Zakiyah 2019). On the one hand, it will have not only a positive impact on the progress of the community but also a negative impact if the community, especially the individual, does not prepare well in adjusting and utilizing existing developments (Nurmala, Triwoelandari & Fahri 2021). Therefore, each individual needs to change basic things such as thinking, acting, and interacting with others and the environment (Kioupi & Voulvoulis 2019). Education has a significant role in helping individuals improve how they think, act and interact by fostering skills that greatly influence individuals' ability to live and develop in the era of globalization. One of the skills is collaboration and communication skills (2C).

Communication is essential in education, especially in teaching and learning activities. The learning process occurs through interpersonal communication, namely through the exchange of ideas, ideas, and information, as well as listening and appreciating the opinions of others or through intrapersonal such as thinking, remembering, and perceiving (Redhana 2019). Communication skill is an important requirement in the learning process because they can help and facilitate the disclosure of ideas and information exchange between teachers and students (Marfuah 2017). In addition, it also helps to improve the good effect between teachers and learners in the teaching and learning process. The ability to communicate creates an atmosphere that encourages active learning where students have the confidence to express their opinions and become suggestions in developing attitudes to appreciate the differences of opinion that they will find in daily life (Putri & Arsil 2020). Thus, it can be said that communication skills have an influence on the activeness of students, as well as helping students to capture information conveyed by teachers easily. Thus, communication skills are needed during the learning process.

In addition to communication skills, students' collaborating skills also need to be trained and developed. These two skills intersect; communication skills support collaboration between fellow students and the environment and vice versa. According to Rohida (2018), fundamentally, the 21st-century era will change various individual activities in various fields. In addition, this century also requires every individual to interact with others and the environment to achieve the stability of human relations towards social, environmental, and economic (Storey, Killian & O'Regan 2017). The form of interaction is collaboration. Collaboration skills are closely related to team or group cooperation to achieve a goal (Cholis & Yulianti 2020). Collaboration can encourage students to achieve effective and meaningful learning and work outcomes (Cholis & Yulianti 2020). In addition, this skill needs to be embedded in the character of students to train the growth of knowledge, increase social interaction and sense of leadership, adept in various roles and responsibilities, work productively, and emergence of empathy among fellow students (Hermawan et al. 2017; Jalmo, Fitriyani & Yolida 2019; Cholis & Yulianti 2020). Thus, an effort is needed to train and improve the skills of 2C students, specifically in the learning process, so that it can be implemented in daily life.

2C students' skills can develop if they are carried out with the right learning process and teaching materials can be understood by students so that they can create interactions that can encourage communication and collaboration between students. Learning activities such as discussion and project-based tasks can be done through experience in school to improve students' 2C (communication and collaboration) skills. Then, physics material is a science that studies nature in the form of discovery and mastery of knowledge, explains facts, concepts, or principles, and analyzes and explains the relevance of science concepts to everyday life (Sutrisno 2019) so that it supports the process of developing students' 2C skills.

Based on the results of preliminary observations conducted on eleventh-grade students of the science program at public senior high school number 2 Palembang, it was known that communication and collaboration skills owned by students already existed, although many still had low 2C skills. It can be seen that when a teacher gave assignments in groups, some students actively argued and discussed completing the task. However, many students still did not contribute to conveying ideas and completing group tasks. Then, when students were delivering the results of group assignments in front of the class, only a few dared to convey the results of their ideas, and many students still did not dare to appear in front of the class. It showed students' lack of collaboration and communication skills in the learning process. The lack of 2C skills mastery is certainly a challenge for teachers to create a generation that dares to express opinions, appear in public and work collaboratively with other students, especially during the Covid-19 pandemic nowadays (Redhana 2019).

The Covid-19 pandemic requires the learning process, which is carried out with distance learning methods, to minimize the transmission level. Distance learning is better known as e-learning (Rochim & Budiyanto 2021). E-learning is a relatively new technology in learning (Riyanti, Susilaningsih & Putra 2021). Although it is a new method, e-learning is considered a learning innovation that adapts to the development of technology, information, and communication (Wahyudi 2017). It has a major impact on learning in the classroom, especially in terms of interaction between teachers and students and students with learning difficulties (Riyanti, Susilaningsih & Putra 2021). Interactions can be done face-to-face with the internet medium so that there is no limited space and time (Riyanti, Susilaningsih

& Putra 2021). Online learning is relatively new in Indonesia, so there are still many adjustments that must be made so that the skills of 2C students can continue to develop by expectations (Andayani et al. 2020). One alternative solution that can be done is to apply the right learning approach, namely the STEM approach (Science, Technology, Engineering, and Mathematics).

STEM-based learning consists of four integrated elements, namely Science, Technology, Engineering, and Mathematics (Muthi'ik, Abdurrahman & Rosidin 2018). STEM is an important issue and an internationally recognized educational trend to improve the skills needed by every individual in the 21st century (Becker & Park 2011; Helmi et al. 2019; Suherman et al. 2021). STEM-based learning focuses on solving problems in the educational process through a project or product that relates to real-world experience in schools, communities, jobs, and global companies (Ismayani 2016; Listiana et al. 2019). The ability of students to analyze, collect, solve problems and understand correlations between surrounding problems can arise through learning with the STEM approach (Pangesti et al. 2017). Through the STEM approach students are required to understand and understand the concept of science and its relationship with the environment so that learning physics in class will be more meaningful for students. In addition, STEM-based learning can also support independent learning curricula that have anticipated the development of life and science in the 21st century (Batubara et al. 2022). The application of learning with a STEM approach can be considered appropriate especially to meet the needs of achieving 2C (communication and collaboration) skills that are useful in the face of the growing 21st century (Mulyani 2019; Sunarti & Rusilowati 2020; Sinurat, Syaiful & Muhammad 2022).

Based on previous research, the STEM approach can foster students' reasoning abilities, critical thinking, creativity, investigation, and collaboration (Sasmita et al. 2021). The application of the STEM approach in the learning process, especially in physics subjects, can improve the collaboration skills of students with high categories (Cholis & Yulianti 2020). Then in another study conducted by Mu'minah & Aripin (2019) shows that the 21st-century skills of students, especially collaboration and communication skills, increased very well after ICT-based STEM learning was implemented. The research conducted by (Wangsa et al. 2017) then conducted research shows an improvement in students' communication skills after learning until the second cycle. In addition, it can create efficiencies in collaboration skills that improve knowledge construction and problem-solving (Stehle & Peters-burton 2019). The results showed that there was a significant increase in student communication and collaboration skills after the learning process with the STEM approach was carried out. This is related to the research that will be conducted, but the difference is in the media that will be used, where researchers use e-learning in teaching and learning activities.

Based on the background of the problem and previous research, this research was conducted to determine the effect of STEM-based e-learning applications on the communication and collaboration skills of upper secondary school students on wave material. It was conducted at public senior high school number 2 Palembang. The results of this study can be used as a reference for creating meaningful learning experiences in improving students' skills.

METHODS

The research was conducted in the even semester of the academic year 2021/2022 at public senior high school number 2 Palembang. The subjects in this study were 59 grade 11 th students at a public senior high school number 2 Palembang. This study used a quasi-experimental method with One Group Pretest-Posttest Design. One group pretest-postest research design is research conducted on a group of students (Fraenkel & Wallen 2012). Through the One-Group-Pretest-Posttest design, it will be seen how the influence of using STEM-based learning is improving students' communication and collaboration skills. The design pattern of one pretest-posttest group is shown in TABLE 1 below.

TABLE 1. Research Design One Group Pretest-Posttest Design

Groups	Pretest	Treatment	Pos-test
Experiment	O_1	X	O_2

In this study, the data collection instrument was a conceptual understanding test and a non-test in the form of a 2C skill observation sheet (communication and collaboration). The concept comprehension tests included a pretest and a post-test. The pretest was given to students before learning using STEM-based e-learning on the characteristic material of mechanical waves and sound waves to improve student communication and collaboration skills. Meanwhile, the post-test was given to students after carrying out the learning process using e-learning. Then, the observation sheet was used in the form of a rubric for the 2C skills assessment (communication and collaboration). Three observers carried out the completion of the rubric to assess the communication and collaboration skills of the students.

The analysis technique of this study was a quantitative data analysis technique to analyze data collected from students' collaboration and communication skills achievement scores. The data were then analyzed using the Paired Sample t analysis technique and the N-Gain Score Test. The Paired Sample t Test served to determine whether there was a difference between before and after learning using STEM-based e-learning. The Paired Sample t Test was calculated using the SPSS version 23 application. The significance level was 5% with the proposed decision criteria of the application of STEM-based e-learning which can improve students' 2C skills if the significance value produced (p-value) is smaller than the specified significance level. Before conducting the test Paired Sample t Test, an assumption test was first carried out, which included a normality test.

Normalized Gain (N-Gain) analysis determined whether STEM-based e-learning was proven effective in improving students' 2C skills. Previous studies by many researchers used normalized gain analysis (Muthi'ik, Abdurrahman & Rosidin 2018; Doyan et al. 2020; Pratama 2020; Khaira, Ritonga & Halim 2021). The formula of the N.Gain value is:

$$N - Gain = \frac{S_{post} - S_{pre}}{S_{\max} - S_{pre}}$$

After obtaining the results of the calculation, then the researcher interpreted the value in the category of the effectiveness of using STEM-based e-learning. The N-Gain criteria can be seen in TABLE 2.

TABLE 2. Effectiveness Categories Based on N-gain (Hake 1998)

N-gain Value Criteria	Category
$N_{gain} \geq 0.7$	High
$0.7 > N_{gain} \geq 0.3$	Medium
$N_{gain} < 0.3$	Low

RESULTS AND DISCUSSION

The application of STEM-based e-learning in physics learning material on the characteristics of mechanical waves and sound waves has been implemented to improve students' 2C (communication and collaboration) skills. As a learning medium that integrates a learning management system (LMS) with a STEM approach, STEM-based e-learning has been specially designed to assist and simplify the learning process and can improve the expected skills. In the learning process using STEM-based e-learning, students were asked to observe the impression of learning videos as an encouragement to start learning, and they were given directions to discuss through discussion forums on e-learning to solve the problems in the discussion forum.

Students were given the freedom to do literacy from any source. Discussion forums, hopefully, can improve students' communication skills. STEM-based e-learning was developed with a virtual laboratory along with learner worksheets to make it easier for students to conduct virtual experiments. A question exercise was available at the end of each lesson to hone the learner's skills after the learning process. In the last learning, students were asked to make project assignments in the form of simple tools related to materials. This activity was carried out to hone students' skills in communicating and collaborating in solving problems, making decisions, and providing opportunities for students to work in the period that has been observed in producing products (Fitriani 2020; Waluyo & Wahyuni 2021).

Students' communication and collaboration skills are expected to increase after the learning process using STEM-based e-learning. The increase in these skills can be seen from the results of student exams that were done before and after learning. The average test results of students are shown in TABLE 3.

TABLE 3. Data on Average Pretest and Posttest Results of Learners

Parameter	Communication		Collaboration	
	Pretest	Posttest	Pretest	Posttest
Number of Students	29	29	30	30
Top Rated	75	100	65	95
Lowest value	26	56	45	75
Average	54	82.7	55	85.7

The data presented in TABLE 3 shows students' learning outcomes after and before implementing STEM-based e-learning. Based on these results, there was an increase in students' pretest and post-test scores on both skills. Communication skills increased by 28.7% while for skills there was an increase of 30.7%. This increase has occurred in previous studies conducted by Alyoussef (2021) and Cholis & Yulianti (2020) stating that STEM-based e-learning can improve students' 2C skills.

Normality test

Subsequent measurements were carried out on students' pretest and post-test data to find out whether the data obtained were normal. The normality test of 2C skill data of students is shown in TABLE 4 and 5.

TABLE 4. Data on Average Pretest and Posttest Results of Learners

Research Variable		Treatment	Description
Collaboration Skills	Pretest	.071	Normal
	Post-test	.125	Normal

TABLE 5. Data on Average Pretest and Posttest Results of Learners

Research Variable		Treatment	Description
Collaboration Skills	Pretest	.071	Normal
	Post-test	.125	Normal

T-Test Sample Paired Test

After the data on students' collaboration skills were normally distributed, paired testing of t-test samples was performed. The results of paired testing of student t-test samples are detailed in TABLE 6 and TABLE 7.

TABLE 6. Output Paired T-test Communication Skills

		Communication
Paired differences	T	-24,519
	Df	30
	Sig. (2-tailed)	.000

TABLE 7. Output Paired T-test Collaboration Skills

		Collaboration
Paired differences	T	-30,377
	Df	29
	Sig. (2-tailed)	.000

The analysis uses the t-test to determine whether there is an effect of STEM-based e-learning during learning. The t-calculation test uses a statistical formula with a significance level of 0.05. The results are the t-count test value for communication skills of 24.519 and collaboration skills of 30.377. Meanwhile, the t-table value is 1,697 with a significance level of 0.05. So it can be concluded that the value of t-count < t-table. Hypothesis testing shows that H1 is accepted, namely that the application of STEM-based e-learning can improve students' communication and collaboration skills. Also, it shows that the use of STEM-based e-learning has a positive impact on increasing students' learning motivation and learning outcomes. The results of this study are supported by previous research on e-learning using the STEM approach to improve 21st-century skills (Suwardi 2021). The successful application of learning using STEM-based e-learning is due to the learning process that has been taught with the correct patterns, namely interesting learning, the use of images, videos, animations, and virtual laboratories so that it can help students to understand learning materials (Hartanto, Marlina & Wiyono 2021) and using media in the form of audio, visual and narrative that are packaged into interactive learning makes students and teachers interested in learning. It is in line with Alyoussef (2021), that the learning process with e-learning is very interesting for students because teaching and learning activities become more interactive and can be accessed easily by students.

N-Gain Test

Furthermore, an N-gain test was carried out to determine the improvement in 2C skills of students seen from the difference between the test results before treatment and after treatment. The average acquisition of N-gain for 2C skills can be seen in TABLE 8.

TABLE 8. Learner 2C Skills N-gain Average Data

Skill	Lowest gain	Highest gain	Average N-Gain	Category
Communication	0.43	1.00	0.62	Medium
Collaboration	0.50	0.89	0.68	Medium

Based on the results of N-Gain 2C skills data of SMAN 2 Palembang students, it is known that the lowest N-Gain value in communication skills is 0.43 and the highest is 1.00 with an average N-Gain of 0.62 in the medium category. Meanwhile, in collaboration skills, the lowest N-Gain value is 0.50 and the highest is 0.89 with an average N-Gain of 0.68 which is included in the medium category. Then, the review of the N-gain score based on aspects of the learner's 2C skill indicator is shown in TABLE 9 for communication skills and TABLE 10 for collaboration skills.

TABLE 9. N-Gain Per-Indicator of Communication Skills

No	Indicators	Pre	Posts	N-Gain
1	Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in several forms and contexts.	55.36	80.65	0.57
2	Listen effectively to understand the meaning	55.76	80.75	0.56
3	Use various media and technologies, and assess their impact	50.29	81.61	0.63
4	Communicate effectively in different environments	52.01	87.64	0.74
Average		**58.53**	**85.30**	**0.62**

Based on the data in TABLE 8, it is known that the average score of N-gain of student communication skills is 0.62, which means that it has a medium category. For n-gain per indicator, the

indicator of communicating effectively in different environments has the highest score of 0.74 with an increase of 35.63% while the indicator of articulating thoughts and ideas effectively by using oral, oral, and nonverbal communication skills in several forms and contexts experiences an increase of 25.29% with an n-gain score of 0.57; listening effectively to understand the meaning experiences an increase of 24.99% with an n-gain score of 0.56 and using various media and technologies and assessing the impact experiences an increase of 31.32% with an n-gain score of 0.63. The three indicators are included in the medium category, namely, in the range $0.7 > Ngain \geq 0.3$, or in other words STEM-based e-learning that has been developed is quite effective to improve students' communication skills.

TABLE 10. N-Gain Per-Indicator of Collaboration Skills

No	Indicators	Pre	Posts	N-Gain
1	Contribution	56.67	93.33	0.85
2	Time Management	45.00	80.00	0,64
3	Problem Solving	49.17	82.50	0.66
4	Working with Others	78.33	91.67	0.62
5	Research Techniques	45/83	80/83	0,65
	Average	58.53	55.00	85.67

TABLE 10 shows that there is an increase in average collaboration skills for all indicators. The first indicator is the contribution, increasing by 36.67% with an N-gain of 0.85 in the high effectiveness category. The second indicator is time management, increasing by 35% with an N-gain value of 0.64 in the medium category. The third indicator is problem-solving, increasing by 33.33% with an N-gain of 0.66 in the medium category. The fourth indicator is working with others increasing by 13.33% with n-gain of 0.62 in the medium category. The fifth indicator is research technique with an average increase of 35% and an N-gain value of 0.65 in the medium category. Overall, the average of students' collaboration skills increases by 30.67% with an N-gain of 0.68 in the medium category. It means that STEM-based e-learning that has been developed is quite effective to improve the collaboration skills of high school students.

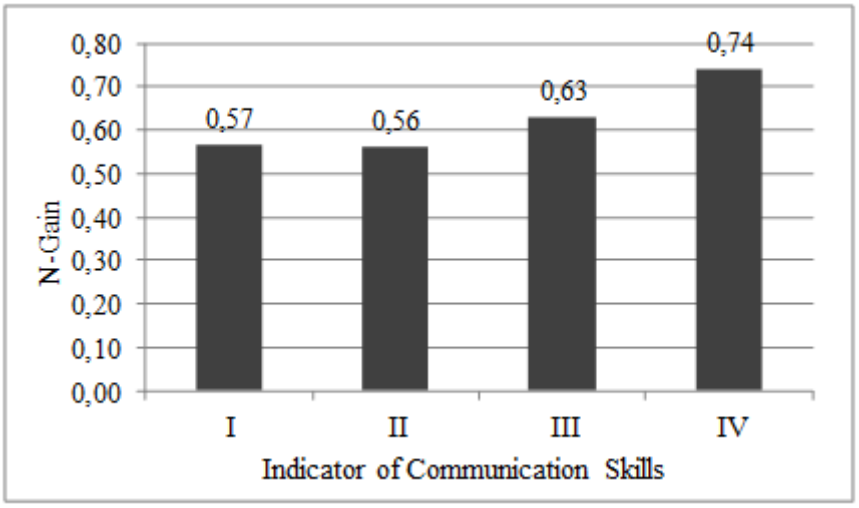

FIGURE 1. Graph N-Gain of each Communication Skills Indicator

Based on FIGURE 1 above, it can be seen that the highest increase is in the indicator of communicating effectively in different environments which is 35.63% while the lowest increase is in the indicator of listening effectively to understand the meaning which is 24.99%.

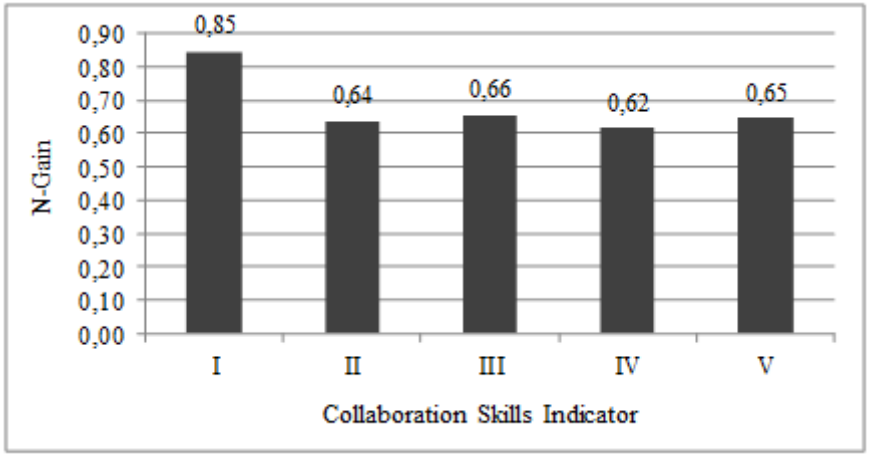

FIGURE 2. Graph N-Gainof each Collaboration Skills Indicator

FIGURE 2 shows that the highest increase is 36.67% in the first indicator, namely contribution while the lowest increase is 13.33% in the fourth indicator, namely working with others. The highest N-gain value is in the first indicator, namely contribution while the lowest increase is in the fourth indicator, namely working with others. It corresponds to the phase of adolescent psychological development, in this case, high school students who are in this phase tend to impose something according to what they want (Ajhuri 2019). So, when students are in situations that require them to work in groups, they will also tend to prefer to be listened to or express opinions compared to listening to the opinions of others. However, their ability as a listener is quite good compared to their ability to give ideas even when they are not working in a group.

Overall, the increase in N-gain scores in each category of 2C skills in TABLE 5 and 6 is due to the application of learning using attractive STEM-based e-learning, so that students are enthusiastic to express their opinions verbally. Also, the communication between students and teachers becomes more communicative. It is in line with research that has been done previously, the use of learning media can arouse the motivation and learning interest of students (Maulida et al. 2021), then the integrating STEM-based physics learning can improve students' collaborative abilities (Cholis & Yulianti 2020). Moreover, the stimulus given by the teacher on e-learning requires students to be active in communicating verbally and in writing so that the application of learning using e-learning can improve students' communication skills (Jufriadi, Rahayu & Ayu 2022).

The results also prove that e-learning provides a positive experience for students in terms of the quality of content, materials, and media displays presented (Martini, Ismet & Wiyono 2021). Also, the integration between project-based learning models and e-learning with an e-learning-based STEM approach to science learning is believed to improve the ability to achieve learning objectives (Rochim et al. 2021). Thus, the application of learning using e-learning has a positive impact on the learning outcomes of students (Haruna, Setiawan & Odja 2021).

CONCLUSION

The use of STEM-based e-learning can be used to improve students' communication and collaboration skills, as indicated by the increase in the average value of students' skills before and after learning using STEM-based e-learning. Also, STEM-based e-learning is effective to improve students' communication and collaboration skills, indicated by the difference in the average N-Gain of students' communication and collaboration skills before and after learning using the STEM learning approach with moderate improvement categories.

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