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SCRATCH ASSISTED PHYSICS LEARNING WITH A STEM APPROACH IN THE PANDEMIC ERA TO DEVELOP 21ST CENTURY LEARNING SKILLS

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ABSTRACT

This century demands that everyone has 21st-century skills. The COVID-19 pandemic era has an impact on education, however, to face the global era, 21st-century skills must still develop in higher education including 21st-century learning skills called 4C skills (Creative, Critical, Collaboration, Communication). The survey of results on students participating in the Mechanics I course shows that creative and critical thinking skills are in a low category, collaboration and communication skills are also in the low category. This study aims to develop 4C skills in the pandemic era through learning Physics in Mechanics course with a Science Technology Engineering and Mathematics (STEM) approach, assisted by Scratch, and to know students' responses to the applied learning. The research subjects were students in the third semester, who took the Mechanics I course as many as 110 people and were divided into three groups. The research method is a quasi-experiment one-group pretest-posttest design. The research instrument consists of essay tests to measure creative and critical thinking skills and observation sheets to measure collaboration and communication skills. The results of data analysis demonstrated that students' 4C skills increased, the average is in the medium category.

Keywords: learning skills of 21st century; pandemic; Physics; scratch

INTRODUCTION

In November 2019, the COVID-19 pandemic began to plague various parts of the world including Indonesia which was first announced on March 2, 2020. This pandemic affected various sectors of people's lives, not only health and the economy but also education. The social distancing policy has resulted in the government issuing special learning policies to minimize cases of COVID-19 transmission. One of the policies is online learning for all students due to social restrictions. The implementation of Education Policies in Emergency Periods is regulated in Circular Letter Number 4 of 2020. The 21st century demands that every human being has 21st-century skills, to compete in this global era. To face global competition in the 21st century, education in Indonesia needs to facilitate the development of 21st-century skills. According to Talmi et al. (2018), the 21st century is marked by the development of new technologies and the rapid pace of change to educate students to face future job competition. To face future job competition, it is necessary to develop skills called 21st-century learning skills. In line with Erdogan and Ciftci (2017), 21st-century learning skills can be developed in all aspects of life. One of them is through education. As Trilling and Fadel (2009) point out, 21st-century learning skills include critical and creative thinking skills, communication, collaboration skills. Critical, creative thinking skills, collaboration,

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and communication skills were identified as 4C by The Partnership for 21st Century Skills (P21).

Physics learning in Mechanics I for the last 3 years has not facilitated the development of 21st-century learning skills, meaning that each lesson has not integrated 21st-century learning skills indicators. The results of the survey on students participating in the Mechanics I course show that their creative and critical thinking skills were in a low category, communication and collaboration skills were also in the low category. The previous studies result of that 21st-century skills can be developed through the STEM (Science Technology Engineering and Mathematics) approach, (Olivarez, 2012; Robert, 2012; Kennedy & Odell, 2014; Yamak et al., 2014; Sahin et al., 2014; Gülhan & Sahin, 2016). Applications of Science, Technology, Engineering, and Mathematics (STEM) in learning can be integrated with learning models to increase students' knowledge (Lestari, et al., 2019). Furthermore, it allows students to gain experience in developing solutions to challenges that will change in the future (Tsai, et al., 2018). In a study conducted by Kubat and Guray (2018), to gain critical and creative thinking, higher-order thinking skills, problem solving and collaboration skills can be used in the Science Technology Engineering and Mathematics (STEM) approach.

Based on the previous research result, STEM can train students in critical thinking (Syukri et al., 2013) and creative thinking skills (Ismayani, 2016). The National Science Foundation (NSF) in the 1990s, introduced that the STEM approach is an acronym for Science, Technology, Engineering, and Mathematics (Bybee, 2013). STEM approach into education with the aims of integrating four disciplines, namely Science, Technology, Engineering, and Mathematics (Ercan et al., 2016). The STEM approach not only focuses on the cross-disciplinary integration of S (Science), T (Technology), E (Engineering), and M (Mathematics), but also focuses on systematic thinking, openness to ethical values, communication, research, problems, creativity production, the intersection of knowledge and skills in science, technology, engineering, and mathematics (Çengel et al., 2019). The STEM approach is assessed as an appropriate approach to be applied in learning and can be combined with other approaches. Overall, based on Yildirim's (2016) research, the STEM approach has a positive impact on activities and learning outcomes in schools, consists of student academic success, motivation, student interests, problem-solving skills, student attitudes towards lessons, critical thinking skills, and scientific process skills. In addition, the research result of Sarı et al. (2017) showed The use of a STEM approach to learning has been shown to be effective in the learning process, assisting students in developing 21st-century skills, increasing interest in the engineering profession, creating a more joyful classroom environment, and assisting students in choosing their future career.

Physics is a science about nature, events, and natural phenomena, and all interactions in it, which in the learning process can facilitate the scientific experience for students. In this study, physics learning with a STEM approach uses Scratch media. Physical phenomena can be visualized using Scratch. Scratch is a visual programming language based on code blocks to introduce basic programming concepts in an interactive and fun way (Hardyanto, 2014). The advantage of Scratch compared to other learning media is that it can involve students actively and independently in making simulations of physical phenomena. Scratch-assisted physics learning makes students know step-by-step physics concepts because Scratch helps develop thinking algorithms and can apply physics equations and formulas into programs. Looking into Meerbaum-Salant et al. (2013) studies, Scratch is proven to be suitable for use in learning. Also, the study of Kalelioğlu and Gülbahar (2014) highlights that Scratch helps students to reason systematically, think creatively, and work collaboratively, all of these skills needed for the 21st century. This study aims to develop 21st-century learning skills of physics education students through the Mechanics I course based on Scratch using the STEM approach and to know the students' responses to the learning applied.

METHODS

The research was conducted at Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, specifically in the laboratory of the Physics Education study program, in the odd semester of 2020/2021. The research design used is Quasi-Experimental Design with One Group Pre-test and Post-test Design (Arikunto, 2013). The research subjects were students of the third-semester physics education study program who took the Mechanics I course totaling 110 students who were divided into three groups. The research design pattern is as follows.

$$O_1 X O_2$$

Description:
X = treatment
O_1 = pretest (before treatment)
O_2 = post test (after tretment)

The three groups were tested for homogeneity and normality using the normality data test called the 'Lilliefors Test' which is a modification of the Kolmogorov-Smirnov Test (Razali & Wah, 2011). The normality data test was performed using the Lilliefors Test on the IBM Statistics SPSS 22 program through the Analyze – Descriptive Statistics – Explore menu. A homogeneity test is carried out using the IBM SPSS Statistics 22.0 program, via the Analyze -Descriptive Statistics – Explore – Plots – Power estimation menu. Homogeneity test statistics analyzes the output of descriptive statistics, namely by reviewing the value of Levene Statistics with the following conditions: (1) Significance value < 0.05 means that the variance of the population group data is not the same (not homogeneous); (2) Significance value > 0.05 means that the variance of the population group data is the same (homogeneous).

The research data collection techniques used documentation, observation, tests, and questionnaires. The research instrument consisted of an observation sheet to measure collaboration and communication skills, a description test to measure creative and critical thinking skills using indicators from Trilling and Fadel (2009), a Linkert scale questionnaire to measure student responses to learning. The indicators of critical thinking are analysis, creating connections, identification. The indicators of creative thinking are originality, new ideas, and realizing creative ideas. The indicators of communication are expressing words clearly, communicating effectively, and using communication for various purposes. The collaboration skills developed in this study include three indicators consisting of demonstrating the ability to work in groups, having flexibility and the ability to compromise to achieve common goals, and sharing responsibility in groups. Analysis of the instrument using validity, level of difficulty, discriminatory power, and reliability tests. The final data analysis used paired samples t-test and independent samples t-test. The data from the observation sheet and questionnaire analysis used percentage descriptive. N gain test was used to know the improvement of 4C skill after treatment.

RESULTS AND DISCUSSION

The physics learning material for Parabolic motion, Momentum and Impulse in the Mechanics I course with a STEM (Science Technology Engineering and Mathematics) approach, assisted by Scratch, was carried out for 2x3x50 minutes or 2x3 credits. The implementation of learning was supported by learning tools with a STEM approach consisting of lesson preparation plans, teaching materials, Student Worksheets, as well as presentation media, videos, and Scratch. The learning tools used to facilitate the development of 21st-century learning skills are different from previous learning tools. The learning system implemented was student-centered using the online PBL (Problem Based Learning) model through the Google Classroom and Google Meeting platforms. Students were directed to conduct group discussions using google meetings and delivered their work in front of the class online, while the lecturer acted as a facilitator. According to the research result of Bevan et al. (2017), that is important in learning to make students the main actors while educators are only facilitators.

The first meeting began with a pre-test, which aimed to determine the early students' abilities. The beginning of the lesson was presenting the problem using a video that described several applications of Parabolic Motion, Momentum and Impulse material, as well as Collisions, this aimed so that students can define the meaning of Impulse and Momentum, then the lecturer gave assignments and motivated them to seek information and explore their curiosity. The students were divided into several groups, during the learning process, each group consisted of 5 students. After the problem was presented, students were directed to discuss it in their respective groups through google meetings. Student activities related to communication and collaboration skills during the learning process were observed and assessed by observers through online learning recordings. Students discussed to understand the definition of momentum and impulse followed by the submission of opinions from each group and then concluded together. Discussion activities facilitate students to develop communication, collaboration, critical thinking, and creative thinking skills. Physics learning with a STEM approach links the material discussed with applications in everyday life. Students were directed to be able to name and explain the application of momentum and impulse on a daily basis. This activity also used the discussion method. Discussions about the application of momentum and impulses in daily life get great enthusiasm from students. Students exchange their opinions, express curiosity, and dare to ask the lecturers.

In the second meeting, it still used discussion and group methods during the learning process. Discussion activities are carried out to understand the material about collisions. In this meeting, students were directed to carry out

simple experimental activities and created simulations using Scratch media related to the material, namely determining the value of the partially elastic collision restitution coefficient. Figure 1 is a simulation using Scratch.

Figure 1. Scratch Simulation

Students seemed enthusiastic and felt happy to make simulations. Learning that can activate creative attitudes is learning that is not a burden but creates feelings of pleasure when learning something new (Abykanova et al., 2016). Besides being fun, Scratch is also easy to use, so it can motivate students to be creative. Due to the ease of use it creates intrinsic motivation, creativity arises as a result of intrinsic motivation increases creativity (Chandrasekera & Yoon, 2018). Thus, Scratch-assisted learning can develop a creative attitude. Along the same lane with the research of Kobsiripat (2015) which stated that the Scratch media program is effective in providing the ability to develop creativity. Up to this point, the experimental activities to facilitate the development of collaboration skills were carried out in groups, to find data collection, students were given the freedom to be creative in experimenting. Each student is given the responsibility to write a report on the results of their experiments. In addition to observing directly, some groups record their experimental activities so that the data obtained is clearer. The PBL-based physics learning activities that are applied also facilitate students to present their work. Students presented experimental reports and answered several questions in the student worksheet according to the experimental results. The learning process was ended by giving a conclusion from the material that has been studied and continued by working on the post-test questions.

The application of STEM-based physics learning in the Mechanics I course on the Momentum and Impulse, Parabolic motion, the material was said to be running well and effectively. In the same vein, Wahyudi et al. (2012) claimed that existing problems can make students proficient in problem-solving and have the skills to participate in groups. Therefore, in Problem Based Learning, it optimizes students' ability to solve problems by understanding and applying concepts.

In this research, critical thinking skills were measured using pre-test and post-test scores after the implementation of STEM-assisted learning with Scratch media. The critical thinking skills developed refer to critical thinking indicators according to Trilling and Fadel (2009), which include reasoning, making connections, and drawing conclusions. The results of the independent sample t-test have obtained the value of Sig. of $0.001 < 0.05$, so it can be concluded that there is a significant difference due to the application of STEM-based physics learning with Scratch media and there is also the development of critical thinking skills. Based on Table 1, the average pre-test and post-test scores were increased. The application of the STEM approach to physics learning with Scratch media can support the improvement of critical thinking skills. This is following the results of research by (Yuliati et al., 2011; Yotiani et al., 2016; Pangesti et al., 2017), that the use of an approach in learning can aid the development of critical thinking skills. A study conducted by Duran and Sendag (2012) demonstrated that learning associated with STEM aspects can help students enhance critical thinking skills significantly. Critical thinking skills develop because they are influenced by the issues presented in teaching materials, consisting of questions and discussions. The issues offered are STEM-related and are designed to encourage students to discuss and solve each difficulty. According to DeJarnette (2012), learning designs that cooperate on STEM challenges and components can pique attention while also honing critical thinking skills. Table 1 shows the results of the examination of each critical thinking indicator's pretest and post-test scores.

Table 1 shows that all of the analysis indicators increased because Problem Based Learning model influenced the students ability to make connections and identify through questions in discussions presented in teaching materials and student worksheets. The questions allowed students to observe various information so that various phenomena can be obtained as a basis for making conclusions. STEM approach learning helps students solve problems and reason to draw conclusions, through science, technology, engineering, and mathematics application (Robert & Cantu, 2012; Lou et al., 2017).

Table 1. Analysis of Pre-Test and Post-Test Scores of Critical Thinking

Critical Thinking Indicators	Grade	Average Score		N-Gain	Criteria N-Gain
		Start	End		
1st Indicator : Analysis	Group 1	42	69	0,40	medium
	Group 2	39	70	0,50	medium
	Group 3	35	68	0,50	medium
2nd Indicator : Create Connection	Group 1	41	65	0,40	medium
	Group 2	44	69	0,40	medium
	Group 3	39	64	0,40	medium
3th Indicator: Identification	Group 1	25	63	0,50	medium
	Group 2	28	65	0,50	medium
	Group 3	24	62	0,50	medium

The increase in analyzing indicators is due to learning carried out through discussions and demonstrations using PBL-based teaching materials and student worksheets that support the improvement of critical thinking skills. In teaching materials and student worksheets, contextual problems are presented which aim to motivate students to find solutions according to the stages of thinking skills. Critical thinking skills are stimulated when students analyze a problem by evidence that support their ideas to solve problems or look for reasons. The critical thinking process is a cognitive process, the learning process begins with identifying problems, analyzing, and then evaluating learning (Abrami et al, 2015; Greene & Yu, 2016). Indicator 3 has increased because the teaching materials used with a STEM approach present questions about understanding concepts. Questions about understanding concepts will require students to practice solving or identifying problems. Someone who has critical thinking skills will be able to identify problems, ask questions to solve problems, convey answers/ arguments, and find other information needed to solve problems. The increase in results is also due to applying Scratch animation, as indicated by Korkmaz's (2016) research, Scratch contributes more to students' logical-mathematical thinking skills.

Indicators of creative thinking consist of originality (authenticity), growing new ideas, and realizing creative ideas. The results of the study are presented in Table 2. Based on Table 2, the average between pretest and post-test scores was increased. Scratch-assisted physics learning with a STEM approach can influence the improvement of creative thinking skills. Scratch is designed to develop creativity, the ability to think systematically and learn in groups, all three of which are basic skills that must be mastered in the 21st century. STEM learning can build students' creativity which is needed to face the 21st century.

The originality indicator has increased because the STEM approach using teaching materials and LKM requires students to find original ideas to solve problems. Learning physics with a STEM approach is effective for increasing students' creativity (Siswanto, 2018). This is suitable to study by Robert (2012) that the STEM approach can instill creativity in problem-solving techniques and can generate creativity and curiosity.

Table 2. Analysis of Pre-Test and Post-Test Scores of Creative Thinking

Creative Thinking Indicators	Grade	Average Score		N-Gain	Criteria N-Gain
		Start	End		
1st Indicator: Originality	Group 1	28	66	0,52	medium
	Group 2	27	67	0,50	medium
	Group 3	25	68	0,50	medium
2nd Indicator: New Ideas	Group 1	31	57	0,37	medium
	Group 2	30	60	0,40	medium
	Group 3	30	60	0,40	medium
3th Indicator: Realizing Creative Ideas	Group 1	29	68	0,48	medium
	Group 2	30	70	0,50	medium
	Group 3	33	66	0,50	medium

The indicator of 'generating new ideas' has increased because learning uses a problem-based method that aims to foster experience and grow new ideas to solve problems. As Abykanova et al. (2016) demonstrated, activities creating new ideas that involve one's experience in finding solutions to problems is a creative process in learning. The findings of Caparo and Slouge (2013) revealed that creative thinking skills can be grown through activities that involve student activity during the learning process. In the student worksheet, there are open-ended questions, the use of open-ended problems can allow students to come up with different solutions and also provide students with a rich learning experience in interpreting problems. Looking to Fauziah's research (2011), in learning activities educators need to encourage students to issue varied answers.

The indicator of 'realizing creative ideas' has increased because learning activities are carried out using STEM-based teaching materials that require students to realize their creative ideas based on the knowledge they gain during the learning process. This finding is according to the studies of Sari et al. (2013) who found that students who have broad knowledge can have high creative thinking abilities. Also, Widiastuti and Ratu (2018) stated that students who have broad insight can provide ideas smoothly. This aspect is assessed from the ability of students when conveying logical ideas and showing understanding of the material being studied. Alkhateeb's research (2018) explained that the application of the STEM approach in the learning process can provide a more supportive classroom environment for developing skills, one of which is creative thinking. The improvement of creative skills is also supported by the application of Scratch media. Scratch can develop a creative attitude, as pointed out by Kobsiripat (2015) that the Scratch media program is effective in giving students the ability to develop creativity.

Communication skills in this research are oral and written communication. The oral communication of students in this research was obtained through observation, while written communication skills were obtained through reports on the results of discussions on the Student Discussion Sheet, as well as reports on experimental results. The communication skills developed in this research include three indicators, namely expressing words clearly, communicating effectively, and using communication for various purposes.

Table 3. Analysis Result of Oral Communication Observation

Communication Indicators	Grade	Average Score		N-Gain	Criteria N-Gain
		Start	End		
1st Indicator	Group 1	59	86	0,61	medium
	Group 2	50	75	0,51	medium
	Group 3	49	74	0,51	medium
2nd Indicator	Group 1	58	85	0,62	medium
	Group 2	55	83	0,62	medium
	Group 3	60	85	0,61	medium
3th Indicator	Group 1	60	87	0,61	medium
	Group 2	56	79	0,50	medium
	Group 3	58	86	0,61	medium

The first indicator of 'expressing words clearly' has increased after STEM-assisted learning has been carried out, with medium improvement criteria. The second indicator, namely communicating effectively, is in the medium category. The indicator of 'using communication for various purposes' is also in the medium category. Learning activities are carried out by utilizing teaching materials, student worksheets, and discussion sheets that require students to actively participate in discussions and deliver the results. The learning process that occurs has been directed since the start of learning. Students must carry out the process of identifying the problems presented, then discussing together with their groups to find solutions to problems. At this stage, activities such as critical thinking are useful for building knowledge in obtaining actual information that can be used to solve problems and draw conclusions or find responsible solutions.

The research result by Oktaviani and Nugroho (2015), that experiment activities and discussions as well as problem-solving results presented in front of the class and in-group can develop

communication skills, while team activities, such as delivering work through presentations, can develop oral communication skills. Communication skills, particularly oral communication, are very important for students' future personal and professional success (Morreale et al., 2017). Students' written communication skills also develop through working on student discussions sheet, worksheets, and making simple reports. Learning that includes discussion activities is more effective to improve oral communication skills so that students can use effective words, form sentences that can be understood grammatically, and use the right voice and intonation when listening and speaking. In line with this finding, Yulianti et al. (2019) found develop oral communication skills, especially indicators of expression of opinion and presented in front of the class, because of using problem-based learning with the STEM approach. Meanwhile, the results of the observation can be seen in Table 4.

Table 4. Analysis Result of Written Communication Observation

Communication Indicators	Grade	Average Score		N-Gain	Criteria N-Gain
		Start	End		
1st Indicator	Group 1	53	68	0,40	medium
	Group 2	50	75	0,50	medium
	Group 3	51	74	0,40	medium
2nd Indicator	Group 1	58	84	0,61	medium
	Group 2	50	76	0,52	medium
	Group 3	51	75	0,50	medium
3th Indicator	Group 1	53	85	0,49	medium
	Group 2	50	75	0,50	medium
	Group 3	52	76	0,40	medium

The three indicators of written communication skills in this study have increased and are in the medium criteria. STEM approach in learning aims to optimize students' participation in the learning process, through analyzing a problem and how to conduct discussions. The research result of Chung et al. (2016) stated that improving written communication skills can stimulate students' reasoning and build social knowledge.

The collaboration skills of students in this study were obtained through observation during the learning process, which was carried out by a team of observers. The collaboration skills developed in this study include three indicators consisting of demonstrating the ability to work in groups, having flexibility and the ability to compromise to achieve common goals, and shared responsibility in groups. The observation results of collaboration skills are presented in Table 5.

Table 5. Analysis of Collaboration Skill Results

Collaboration Indicators	Grade	Average Score		N-Gain	Criteria N-Gain
		Start	End		
1st Indicator	Group 1	62	90	0,5	medium
	Group 2	64	91	0,6	medium
	Group 3	61	91	0,5	medium
2nd Indicator	Group 1	67	92	0,5	medium
	Group 2	64	88	0,4	medium
	Group 3	64	93	0,5	medium
3th Indicator	Group 1	63	90	0,5	medium
	Group 2	62	91	0,5	medium
	Group 3	59	90	0,6	medium

The collaboration skills on the three indicators have increased which shows the medium criteria. This increase is because all students are required to contribute to solving problems presented in teaching materials, student worksheets, and discussion sheets. Teaching materials, student sheets, and discussion sheets contain questions that train students' ability to seek answers from various sources to build their knowledge. Learning activities are carried out in discussions to foster an attitude of cooperation between students in solving problems. This study according to research by Van Leeuwen et al. (2015) reported that through collaboration or group work completing assignments, students are facilitated in exchanging ideas and engaging in discussions. Practicum activities in groups, facilitate the development of collaboration skills that allow students to contribute to groups, be responsible, and respect each other's opinions to reach an agreement so that the subject matter is easier to understand. Also, in the study of Thibaut et al. (2018), the learning is based on shared experiences, not individuals, and clearly stated that knowledge is actively built by students.

The Scratch media used has a shared facility that allows students to share projects and support from fellow scratch users and get feedback and can even learn from projects done by other users, so collaboration can emerge. Activities undertaken to build collaboration will usually involve the division of tasks, respect for each other's opinions, and the attitude of responsibility of each individual in completing each work to achieve a common goal. Asmawati et al. (2013) found out that applied collaborative learning has succeeded in increasing students' learning activities. In addition, this is also in line with the results of research by Yulianti et al. (2019) that problem-based learning using the STEM approach develops collaboration skills or collaboration because learning activities are carried out in groups to foster cooperative attitudes among students in solving problems.

The responses of students participating in the Mechanics 1 course assisted by Scratch with a STEM approach show that it was the effective learning applied in developing 21st-century learning skills with an average score of 77.33%, which means good category. This is in line with the statement of Beers (2011) that the learning process with the STEM approach contributes to the development of 21st-century learning skills. Similarly, Kanadhi's research (2019) showed that the learning process with the STEM approach is suitable to be applied in physics subjects.

CONCLUSION

Based on the research results, several conclusions were obtained that Scratch-assisted physics learning with a STEM approach can develop 21st-century learning skills which include students' creative thinking skills, critical thinking skills, collaboration skills, and communication skills. The development of creative thinking skills, critical thinking skills, communication skills, and collaboration skills are in the medium category, this is because the meeting only took place twice, however, it can already illustrate that the implemented learning can develop critical thinking, creative thinking, collaboration, and communication skills. Indicators of critical thinking skills consist of reasoning, making connections, and drawing conclusions. Indicators of creative thinking include originality (authenticity), growing new ideas, and realizing creative ideas. Communication indicators are expressing words clearly, communicating effectively, and using communication for various purposes. Collaboration indicators consist of showing the ability to work in groups, having flexibility, and the ability to compromise to achieve common goals. This research can be continued on other physics materials so that the improvement can be seen as real. The responses of students participating in the Mechanics I course assisted by Scratch are in a good category.

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