PILLAR OF PHYSICS EDUCATION
Vol. 17 (2), 2024, page.157-166
ISSN (Print) : 2337-9618
ISSN (Online) : 2684-8880

Improving Students' Collaboration Skills by using STEM-Engineering *Design Process (Edp)* on Motion and Force Materials

Jihan Mutiara Fatiin[1], Nanang Winarno[2], Achmad Samsudin[3], Yuyun Wahyuningsih[4], Popi Nurhaida[4]

[1] *Science Teacher Professional Education (PPG Prajabatan), Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, 40154, Indonesia*
[2]*Departement of Science Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, 40154, Indonesia*
[3] *Departement of Physics Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, 40154, Indonesia*
[4]*SMP Negeri 29 Bandung, Jl. Geger Arum No. 11A, 40154, Indonesia*

Corresponding author. Email:nanang_winarno@upi.edu

ABSTRACT

Along with the times, globalization has an increasingly obvious impact with opportunities and challenges that every individual must face simultaneously without exception. Education has an important role in shaping the nation's generation, which is ready to face the challenges of the 21st century. Indonesia has made efforts in this regard through the implementation of the Merdeka Curriculum which prioritizes the 6 pillars of the Pancasila Student Profile which is considered the basis for shaping the character of students. Collaboration skills are part of the pillar of mutual cooperation in the Pancasila Learner Profile and are very important for students to develop. This study aims to analyze the improvement of students' collaboration skills by using the STEM-Engineering Design Process (EDP) on motion and force. This research used a pre-experimental method with One Group Pretest-Posttest. The data collection tool used in this study is a Self-Assessed Contribution Skills (SACS) questionnaire. This research was conducted in one of the schools in Bandung, Indonesia. The subjects in this study were 34 seventh-grade students consisting of 16 boys and 18 girls. The results showed a significant increase in students' collaboration skills with a mean pretest of 63% and a mean post-test of 67%. The N-Gain score on the Information Sharing dimension was 0.24, the Group support dimension was 0.07, and the Group Learning dimension was 0.08. Based on the study's results, STEM-Engineering Design Process (EDP) learning can be an alternative for teachers in improving students' collaboration skills, especially in science lessons.

Keywords :STEM; Engineering Design Process; Collaboration Skills.

I. INTRODUCTION

Globalization has an impact on the development of all aspects of life today. These conditions provide opportunities as well as challenges for each individual. Advances in technology and information demand an increase in the quality of human resources [1]. In this case, education has a very important role in preparing students through various skills that can support their quality in the future. In addition to technological and information advances, the 21st Century challenges faced by the world of education include various competencies in social life, including skills in questioning, creative thinking, critical thinking, decision making, and problem-solving so that they can select and interpret the information received, and produce new knowledge [2]. These challenges need to be faced with careful preparation through the implementation of education. The current curriculum also needs to be modified to meet the needs of the 21st-century challenges.

Education in Indonesia has made efforts to prepare for the challenges of the 21st Century by implementing the Merdeka Curriculum. This curriculum prioritizes the development of the Pancasila Learner Profile, which includes pillars of faith in God Almighty, piety and noble character, global diversity, cooperation, independence, critical thinking, and creativity [3]. These six pillars are expected to shape students into individuals who have faith good morals, intellect, and various skills that can support them in facing competition in the future.

Collaboration skills are part of the pillars of cooperation in the Pancasila Learner Profile, which students must develop to train good cooperation attitudes, responsibility, initiative, and sensitivity to their surroundings. The characteristics of students who have been competent in collaboration skills are being able to adapt to heterogeneous groups, being responsible for completing tasks, respecting the opinions of others, and respecting others in their group [4].

Based on the results of observations in class VII in one of the schools in Bandung, it was found that the level of collaboration skills of students needs to be improved because students are still reluctant to group with other students, lack of initiative and contribution in group work, poor interaction between group members, and several other factors that ultimately affect the lack of quality of group work results. Previous research states that students' collaboration skills need improvement if most are individualistic and less responsible for group tasks [5]. In addition, the individualistic attitude of students results in a lack of concern between students, reduced solidarity, empathy, and a lack of respect for others [6].

Based on these observations, it can be said that students' collaboration skills need to be improved through collaborative and learner-centered learning. Therefore, researchers are interested in researching "Improving Students' Collaboration Skills by Using STEM-Engineering Design Process (EDP) on Motion and Force Material".

Collaboration skills can be trained through collaborative learning that is centred on students, one of which is a discussion between students about a problem [7]. Discussion activities carried out by students can improve collaboration skills because, in discussion activities, students are directed to interact by conveying ideas, respecting other people's opinions, and training them to work together to find solutions to existing problems.

In addition to discussion activities, collaborative skills in science learning can be improved through other activities, such as problem-solving through prototype design carried out in groups, one of which is through learning with the STEM model. Kapilla and Iskandar stated that the implementation of STEM (Science, Technology, Engineering, and Mathematics) in learning could encourage students to be able to design, develop and utilize technology, hone cognitive, manipulative, and effective, and apply their knowledge [8]. Therefore, STEM is suitable to be applied in science learning. As in previous research, STEM learning can facilitate students in developing collaboration skills more optimally with an increase in indicators of working effectively with respect, contributing, and being responsible [9].

The Engineering Design Process (EDP) is a part of STEM that introduces students to perform activities similar to those of an engineer as part of the learning process [10]. Engineering Design Process (EDP) can encourage students to learn from experience through engineering stages to be able to find a solution to a problem [11]. Schubert et al. stated that the Engineering Design Process (EDP) is a decision-making process that is usually repeated by applying basic science, mathematics, and engineering concepts to find solutions to achieve a goal [12]. The series of activities in the STEM-Engineering Design Process (EDP) requires good cooperation between students in groups to find solutions, determine designs, and design projects.

Several previous studies related to STEM learning were conducted on collaboration skills and physics problem-solving skills [13], as well as STEM PjBL learning on critical thinking skills [14], STEM-PjBL on problem-solving ability [15], STEM-Virtual Laboratories (PhET) on problem-solving skills [16], while this research was conducted using STEM-Engineering Design Process (EDP), namely STEM with the Engineering Design Process (EDP) stage in learning activities that lead students to be able to collaborate in making designs through story board panels, creating projects, testing projects, to redesigning and improving projects that have been made, namely the 'wind-powered car' project on Motion and Force material. The project also utilizes unused materials that are around.

This study was conducted to determine whether or not there was an increase in students' collaboration skills after STEM-Engineering Design Process (EDP) learning on Motion and Force material.

II. METHOD

1) Research Design

Your The method used in this research is *pre-experimental,* using one research group without a control class [17]. In this study, the implementation of the *Engineering Design Process (EDP)* model as an independent variable and the collaboration skills of students on motion and force as the dependent variable.

The research design used is *One group pretest-posttest*. This design is used not only to observe and measure the impact of the treatment given but also pay attention to the conditions before the treatment is given so that the two can be compared. This research design can be seen in Table 1.

Table 1. Research Design

O	X	O
Pretest	Treatment	*Posttest*

This research uses the *Engineering Design Process (EDP)* stages developed by Bamberger (2013) which include 1) *defining the problem*; 2) *gathering information*; 3) *planning;* 4) *designing*; 5) *testing*; 6) *evaluating;* 7) *redesigning;* and 8) *communicating* [18].

2) Subject Research

The school chosen as the place to conduct the research is one of the schools in Bandung City that has implemented the Merdeka Curriculum. The population in this study was 34 seventh-grade students with an age range of 13-14 years as a sample. The students who were determined to be the sample were selected because they were available for research, namely 16 males (47%), and 18 females (53%). The sampling method used in this study was *Convenience Sampling*. The research subjects can be seen in Table 2.

Table 2. Research Subjects

Research Subject	Total	Percentage
Male	16	47%
Female	18	53%
Total	**34**	**100%**

3) Research Instruments

The instrument used in this study is a questionnaire of students' collaboration skills given before and after treatment in the form of STEM-Engineering Design Process (EDP) implementation. The questionnaire used is Self-Assessed Collaboration Skills (SACS) developed by Hinyard et al. [19]. The questionnaire consists of 2 questions on the information sharing dimension, 3 on the group support dimension, and 6 on the learning dimension. The questionnaire uses a Likert scale of 1 - 7, ranging from strongly disagree to strongly agree.

Specifically, the information sharing, team support, and learning dimensions have Cronbach α scores of 0.67, 0.84, and 0.86, respectively. The three dimensions showed significant correlations with each other. In particular, the information sharing dimension was positively correlated with the team support and learning dimensions with r ¼ 0.39 and r ¼ 0.45, respectively. In addition, the team support and learning dimensions were positively correlated with r ¼ 0.72. [19].

4) Data Analysis

Data analysis was carried out to measure students' collaboration skills using Microsoft Excel and SPSS by calculating *pretest* and *posttest* scores. The data analysis process is carried out through several stages as follows:

Test Item Scoring

There are 11 questions in the collaboration skills questionnaire with 2 questions for the Information Sharing dimension, 3 for the Group Support dimension, and 6 for the Group Learning dimension. The rubric used in assessing test items is a Likert scale of 1 - 7, so the maximum score is 77.

A positive statement sentence will be worth 1 if the learner answers Strongly Disagree, worth 2 if answering Disagree, worth 3 if answering Moderately Disagree, worth 4 if neutral, worth 5 if answering Moderately Agree, worth 6 if Agree, and worth 7 if answering Strongly Agree. Conversely, a negative statement sentence will be worth 1 if the students answer Strongly Agree, worth 2 if they answer Agree, worth 3 if they answer Agree Enough, worth 4 if they are neutral, worth 5 if they answer Disagree Enough, worth 6 if they Disagree, and worth 7 if they answer Strongly Disagree.

Normality Test

The normality test is carried out to determine the normality of the data distribution. This test is widely used for parametric statistical analysis. Researchers used the SPSS version 25.0 program to conduct the Shapiro-Wilk normality test because the sample size was less than 50.

Paired Sample T Test

The Paired Sample T Test was conducted to test the significance of the difference in mean scores obtained by a group based on *pretest* and *posttest* scores. The significance value is 0.05 and determines the hypothesis.

N-Gain Calculation

The N-Gain test is a method used to measure improvement based on the difference between the initial test results and the final test. The N-Gain test was conducted using the following formula [20].

$$\text{Skor N} - \text{Gain} = \frac{\text{Skor } Posttest - \text{Skor } Pretest}{\text{Skor Maksimum} - \text{Skor } Pretest}$$

After the calculation using the formula, the N-Gain score was interpreted based on the table presented below [20].

Interpretation of N-Gain Score

N-Gain Score	**Interpretation**
g < 0,3	Low
0,3 ≤ g ≤ 0,7	Medium
g > 0,7	High

5) Research Procedure

There are 3 main stages in the research procedure, namely planning, implementation, and reporting. In the planning stage, researchers first identified the problems to be studied, then determined the dependent and independent variables, then prepared the necessary instruments, namely the *Self-Assessed Contribution Skills (SACS)* questionnaire rubric.

At the implementation stage, the researcher gave a questionnaire as a *pretest* before implementation, then implemented the STEM-Engineering *Design Process (EDP)* model in learning science material on Motion and Force, and then gave a questionnaire as a *Posttest* at the last meeting. In the final stage of the research, namely reporting, researchers analyzed the data that had been obtained, then concluded the results.

The STEM-Engineering *Design Process (EDP)* in this study uses the stages Bamberger (2012) developed as presented in Table 4 [18].

Table 4. STEM-Engineering *Design Process (EDP)* Learning Stages

Learning Stages	**Learning Activities**
Defining the Problem Students identify the problem, then design and determine the project success criteria.	• The teacher provides a problem related to the project concept that students must identify, namely: 1) How to build a car that can go straight, fast and the farthest? 2) How to make it look neat and attractive at a low cost? • Students design a 'wind-powered car' • Students determine the success criteria for making a 'wind-powered car'
Gathering Information Students identify constraints, as well as weaknesses and shortcomings that may be present in the design.	• Students identify possible constraints on their 'wind-powered car' design. • Students identify the possible advantages and disadvantages of the 'wind-powered car' design.
Planning Students develop a plan for their project in the form of a *Storyboard Panel* with design drawings and descriptions, and an explanation of why they believe their project will succeed.	• Students determine the steps for making the 'wind-powered car' project on the *Storyboard Panel* with pictures and descriptions. • Students provide reinforcing reasons that the planned project will be successful
Create Students make the project according to the plan that has been developed. Students will discover and reflect on the difficulties encountered while modeling and find solutions to these difficulties.	• Students carry out the 'wind-powered car' project • Students determine solutions to difficulties encountered during project implementation
Testing Students test the projects they have made.	• Students test their 'wind-powered car' project
Evaluate Students reflect on and record achievement of project success criteria, and evaluate them. Students identify and explain ways they can improve the design, and gather additional	• Students reflect and record the results of project testing based on the achievement of the criteria that have been made. • Students determine and record solutions for improvement of the design that has been made.

information if needed.	• Students gather additional information if needed
Redesign Students create a new *Storyboard Panel* showing the improved design with a description, then submit it to the teacher for approval. If so, then students are allowed to return to the 'Create' stage.	• Students create a new *Storyboard Panel* that shows design improvements with descriptions • Students propose design improvements to the teacher • The teacher evaluates the design proposal and gives suggestions • Students continue to make design improvements
Communicating Students present their work during the lesson, identifying how they created the design, the results of testing their work, then how they improved the design after testing, what the strengths and weaknesses of their design are, and what they have learned from other teams' designs.	• Students present the results of their work in the form of a 'wind-powered car' starting from the process of making, testing, repairing, to the final result which is delivered orally and by video. • All works are displayed together (make a small competition)

The implementation of the STEM-Engineering Design Process (EDP) model in learning Science Motion and Force material is carried out for 3 meetings with 2 lesson hours at each meeting or for 80 minutes at each meeting. At the first meeting, students carried out the stages of defining the problem, gathering information, and planning. In the second meeting, students create, test, and evaluate projects. Finally, in the third meeting, students redesign the project and communicate it by presenting the project results and showing a video of the project creation.

III. RESULTS AND DISCUSSION

Students' collaboration skills in this study refer to the dimensions developed by Hinyard, Katie, Eileen, and Anthony in the *Self-Assessed Collaboration Skill (SACS)* rubric which includes information sharing, group support, and group learning [19]. The questionnaire was administered twice, namely as a *Pretest* conducted at the beginning before any intervention, and as a *Posttest* conducted after the implementation of STEM-Engineering *Design Process* learning.

Students' collaboration skills are improved through the percentages generated in the *pretest* and *posttest.* The graph in Figure 1 shows the overall increase in students' average collaboration skills.

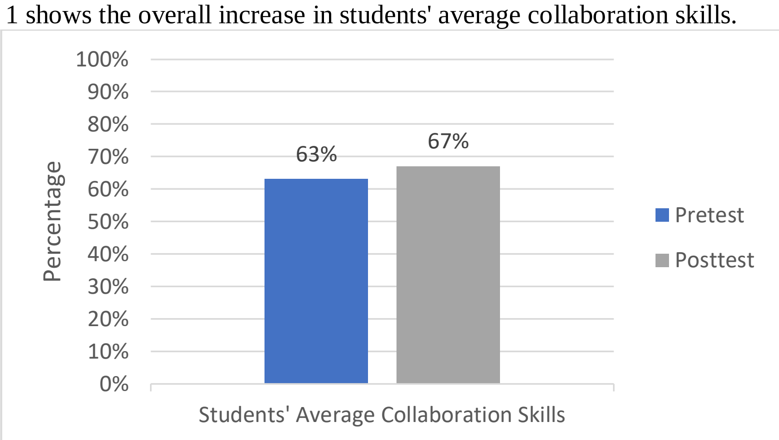


Figure 1. Graph of the Students' Average Collaboration Skills

Figure 1 visually represents the improvement of students' collaboration skills after the implementation of STEM-Engineering *Design Process* learning.

Furthermore, the data obtained was tested for normality. Data normality testing was carried out using the Shapiro-Wilk test and it was found that the significance value of the *Pretest was* 0.892, and the *Posttest was* 0.455. Both values are greater than 0.05 so it can be concluded that the data is normally distributed. The data obtained in the normality test is shown in Table 5.

Table 5. Normality Test

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Pretest	0.984	34	0.892
Posttest	0.970	34	0.455

The results of the normality test in Table 5 show that the data is normally distributed, so the appropriate statistical test is the Paired Sample T Test, which is the result shown in Table 6.

Table 6. *Paired Sample T Test* Results Table

				95% Confidence Interval of the Difference				
	Mean	***Std. Deviation***	***Std. Error Mean***	***Lower***	***Upper***	**t**	**df**	***Sig. (2-tailed)***
Pretest-Posttest	-1.91176	3.90313	.66938	-3.27363	-.54990	-2.856	33	.007

Decision-making on statistical tests is based on the acquisition of a significance value (Sig.), namely if the Sig value is high. (2-tailed) <0.05, then the null hypothesis (H0) is rejected, and the alternative hypothesis (Ha) is accepted [21]. H0 means that there is no effect of using the STEM-Engineering *Design Process (EDP)* on improving students' collaboration skills, and Ha means that there is an effect of using the STEM-Engineering *Design Process (EDP)* on improving students' collaboration skills.

The statistical test results show that the *Sig. (2-tailed)* is 0.007. This value is lower than 0.05, so it can be seen that learning using the STEM-Engineering *Design Process (EDP) significantly improves* students' collaboration skills. Furthermore, the *paired sample T test results are supported by the N-Gain score comparison between the pretest and posttest. The* N-Gain score obtained shows a significant increase in students' collaboration skills as shown in Figure 2.

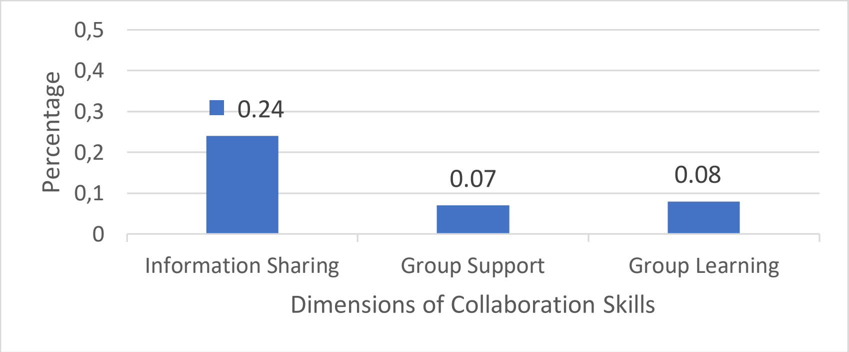


Figure 2. Comparison of N-Gain Scores of Collaboration Skills on Each Dimension

Figure 2 compares N-Gain scores obtained in each dimension of collaboration skills. The N-Gain scores that have been obtained in each dimension are then interpreted using the existing provisions. The three dimensions obtained N-Gain scores lower than 0.3 so that it can be interpreted that the three dimensions obtained low N-Gain scores. The Information Sharing dimension is the dimension with the highest N-Gain score, which is 0.24. The information sharing dimension is related to the awareness and ease of students in sharing information with their groups, and includes skills in communication. Patrick, S. & Lohndorf (2015) said that collaboration involves a transparent and trusted communication process with all members obtaining information and channeling ideas to their group members. Collaboration skills can grow when there is an exchange of ideas between group members and have a sense of mutuality towards their peers [22].

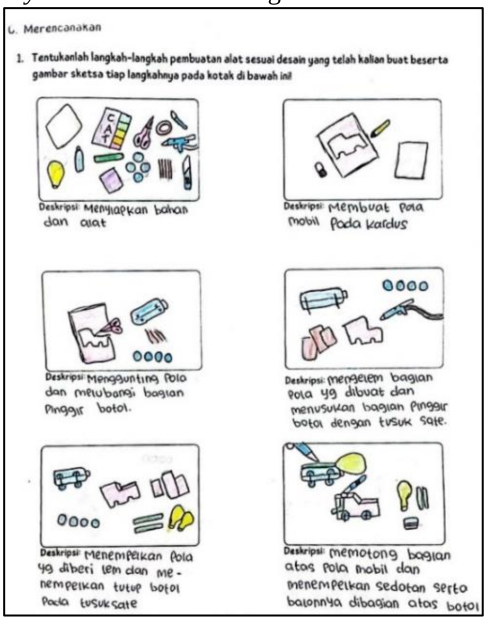
The Group Support dimension improved by obtaining an N-Gain score of 0.07. Despite the increase, the Group Support dimension became the dimension with the lowest N-Gain. This happened because in its implementation, students were grouped randomly with different cognitive abilities and with members who were not their previous study groups so that they needed to adapt again to communicate and cooperate well. As stated by Aliyah (2016), discussion activities in groups can increase learner empathy because students can learn to communicate well, mutual understanding, respect for different perspectives, and empathetic attitudes that can affect relationships in interactions between students [23]. On the other hand, heterogeneous group formation will make students need each other because of differences in the group, such as achievement level and gender. Students who have low achievement need students with high achievement to help them understand the material being studied, and vice versa. The existence of this mutual need will make students collaborate in their learning groups [7].

The Group Learning dimension has increased with an N-Gain score of 0.08. The Group Learning Dimension on Collaboration Skills includes participation and cooperation between group members in achieving goals and making decisions in the group. This is in line with Patrick, S. & Lohndorf's (2015) statement that *"Collaboration occurs when people work with others from different external organizations (e.g. local* *community, vendors, another campus, businesses) or within their own institution (e.g. across silos, functions, schools, divisions) to achieve a clearly understood and mutually beneficial, shared set of goals and outcomes that they could not achieve working by themselves"* [24]. The statement means that collaboration occurs when people work with others from different external organizations (e.g. local communities, vendors, other campuses, businesses) or within their own institutions (e.g. across silos, functions, schools, divisions) to achieve a clearly understood and mutually beneficial set of shared goals and outcomes that they could not achieve working by themselves". In addition, this is also supported by Greenstein who states that collaboration skills are the ability to work together effectively and respect their heterogeneous group members, practicing fluency and participation when discussing decisions in order to achieve their common goals [25].

The STEM-Engineering *Design Process (EDP)* learning implemented in this study includes problem-solving discussions, determining project design, identifying problems in the designed project, improving project design, and presenting project results. The series of activities are carried out in groups to encourage students to contribute more to group work by sharing knowledge, ideas, and experiences. This is in line with previous research that the implementation of STEM in learning in developing collaboration skills allows students to share knowledge, experience, responsibility, and creativity more effectively [9].

In the early stages of learning, students identify problems given by the teacher regarding the project to be carried out, then find solutions together through group discussion activities to gather the necessary information. In this activity, each group member will collaborate in finding solutions by expressing various opinions, then determining the best solution based on the results of their discussion and evaluation [26]. In this activity, students also assess the extent to which the solutions submitted comply with the criteria and constraints set on the problem [27]. When students engage in engineering design-based activities, they are exposed to the iterative and exploratory nature of the engineering process, and by exploring possibilities and embracing creativity, they learn to understand problems from multiple angles, culminating in the development of practical and intelligent solutions [28].

STEM-Engineering *Design Process (EDP)* helps and trains students to develop skills to design a product or project to solve existing problems. Project design requires a clear sequence of steps. STEM learning directs students to think like a designer who designs a product. As stated by Bozkurt Altan and Tan (2021), creative designers must consider different approaches and draw solutions that can be applied to similar problems [29]. Therefore, in STEM-Engineering *Design Process (EDP)* learning, there is an activity of making *storyboards* by students to make it easier for students to determine the steps in making projects. *Storyboards* help students break down key concepts and evaluate the results at each stage [30]. The preparation of project steps by students through *storyboards is* shown in Figure 3.



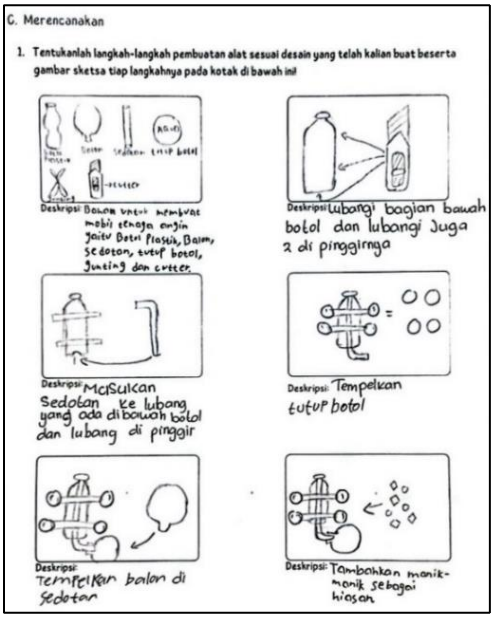


Figure 3. *Storyboard* in Project Creation

After compiling the steps of making the project through the *storyboard,* students begin to collect the materials needed in making the project in the form of simple materials found around or the environment, such as plastic straws, cardboard, milk boxes, plastic bottle caps, and so on. Uzel and Bilici (2021) state that *engineering design-based* activities can be carried out using simple materials that make it easier for students to find solutions to problems faced in a real context [31]. The results of the project carried out by students in the form of a wind-powered car by utilizing simple materials are shown in Figure 4.

Figure 4: Wind-powered Car Project Results

The testing and evaluation stage is carried out after the project is completed to determine the effectiveness of the function and the achievement of predetermined criteria, including walking straight, fast, and far. At this stage, students can also find out the problems or obstacles contained in the product so that students are trained in identifying problems and finding the right solution to improve the project. Careful analysis in testing will help students identify parts that need to be refined to increase the design's effectiveness [28].

After testing and evaluating, students redesign by again using a *storyboard* that shows the steps of improvement to the project, then return to the 'making' stage to make improvements to the parts needed. Next, students enter the final stage which is communicating. Communication is an important part of teamwork [32]. At the communication stage in this learning, students convey their ideas and project results in groups to other students by presenting in front of the class to get feedback, followed by the teacher's reinforcing information [27].

During the learning process, students are more intensive in discussing, which is quite helpful in increasing good interactions between students in their groups. They can foster empathy and initiative to help each other complete tasks. As stated by Trilling and Fadel, the benefits of collaborative learning are fostering individual and collective knowledge, increasing social interaction, and the emergence of empathetic attitudes towards other students [9].

Basically, collaboration skills are the ability to participate in any activity to foster good relationships with others, respect each other, and work together in teams to achieve a goal [33]. In this study, group work in creating a wind-powered car project is a goal that must be achieved and done well by all members of the learner group. Students' collaboration skills can be reflected based on group work, starting from the division of tasks, cooperation in implementation, task completion time management, and group work results. Good work results, on time, and involving each member to contribute can reflect the high collaboration skills of a group.

IV. CONCLUSION

This Collaboration skills are a skill that can help students prepare themselves to face the challenges of the 21st century, so they need to be trained, one of which is through learning activities. This research proves that there is a significant increase in students' collaboration skills after learning STEM-Engineering *Design Process (EDP)*. The increase is indicated by the difference in the level of collaboration skills of students between before and after the implementation of the STEM-Engineering *Design Process (EDP)* with the acquisition of the average *pretest* score of 63% and the average *posttest of* 67%. The improvement of collaboration skills in each dimension after the implementation of the STEM-Engineering *Design Process (EDP)* in learning science material on motion and force is shown through the acquisition of the N-Gain score. The information sharing dimension increased with the highest N-Gain score of 0.24, the Group Support dimension increased with the lowest N-Gain score of 0.07, and the Group Learning dimension increased with an N-Gain score of 0.08. Based on the representation of the N-Gain score, the three dimensions are interpreted as obtaining a low N-Gain.

STEM-Engineering *Design Process (EDP)* learning can train students to contribute more in group work, either through real action or sharing ideas and knowledge with their group mates. In addition, STEM-Engineering *Design Process (EDP) learning can* also train students to interact better with their peers through discussion activities and other collaborative activities included in a series of *engineering design process* learning activities

ACKNOWLEDGMENT

Thank you to grade VII stdents and science teachers of a school in Bandung, lecturer, and colleagues involved in research and writing this journal.

REFERENCES

[1] H. Heriansyah, "The Impacts of Internationalization and Globalization on Educational Context," *Journal of Education and Learning,* vol. 8, no. 2, pp. 164-170, 2014.

[2] H. W. Rawung, D. A. Katuuk, V. N. J. Rotty and J. S. J. Lengkong, "Curriculum and its challenges in the 21st century," *Journal of Education Management Bahana,* vol. 10, no. 1, pp. 29-34, 2021.

[3] R. Widya, R. Salma and E. P. Ranti, Penguatan Profil Pelajar Pancasila, PT. Sonpedia Publishing Indonesia, 2023.

[4] R. A. Sani, Pembelajaran Berbasis HOTS Edisi Revisi: Higher Order Thinking Skills, Tira Smart, 2019.

[5] S. Ilma, M. H. I. Al-Muhdhar, F. Rohman and Murni, "Students Collaboration Skills in Science Learning," in *Advances in Social Science, Education and Humanities Research*, 2020.

[6] Mithhar, A. Agustang, A. Adam and A. Upe, "Online Learning and Distortion of Character Education in the Covid-19 Pandemic Era," *Weebology Special Issue on Computing Technology and Information Management,* vol. 18, pp. 566-580, 2021.

[7] S. I. Khoirunnisa and E. Sudibyo, "Profil Keterampilan Kolaborasi Siswa SMP dalam Implementasi Model Pembelajaran Kooperatif Tipe STAD," *ScienceEdu,* vol. 6, no. 1, pp. 89-97, 2023.

[8] Riyanto, R. Fauzi, I. M. Syah and U. B. Muslim, Model STEM (Science, Technology, Engineering and Mathematics) dalam Pendidikan, Widina Bhakti Persada Bandung, 2021.

[9] M. R. N. Cholis and D. Yulianti, "Pembelajaran Fisika Berbasis Science Technology Engineering and Mathematics (STEM) untuk Mengembangkan Keterampilan Kolaborasi," *UPEJ Unnes Physics Education Journal,* vol. 9, no. 3, pp. 249-255, 2020.

[10] F. Muslihah, N. Winarno, A. Fajarwati and Sujito, "Enhancing Students’ Nature of Science Using STEM Engineering Design Process in Elementary, Compounds, and Mixtures Topic," *Jurnal Kependidikan,* vol. 13, no. 2, pp. 1479-1498, 2024.

[11] A. Fajarwati, N. Winarno and E. C. Prima, "Investigating Students’ Creativity through STEM Engineering Design Process in Element, Compound, and Mixture Topic," *Indonesian Journal of Teaching in Science, ,* vol. 4, no. 1, pp. 69-84, 2024.

[12] M. B. Ulum, P. D. A. Putra and L. Nuraini, "Identifikasi penggunaan EDP (Engineering Design Process) dalam Berpikir Engineer Siswa SMA melalui Lembar Kerja Siswa (LKS)," *Jurnal Riset Dan Kajian Pendidikan Fisika,* vol. 8, no. 2, pp. 53-63, 2021.

[13] M. Khairani, Jasruddin and M. Arsyad, "The Effect of STEM Approach and Student’s Collaboration Ability on Physics Problem Solving Skill," *International Journal of Social Science and Human Research,* vol. 7, no. 3, pp. 1672-1676, 2024.

[14] K. Kurniahtunnisa, Y. U. Anggraito, S. Ridlo and F. Harahap, "STEM-PjBL Learning: The Impacts on Students Critical Thinking, Creative Thinking, Communication, and Collaboration Skills," *Jurnal Penelitian Pendidikan IPA,* vol. 9, no. 7, p. 5007–5015, 2023.

[15] E. Purwaningsih, S. Sari, A. Sari and A. Suryadi, "The Effect of STEM-PjBL and Discovery Learning on Improving Students' Problem-Solving Skills of Impulse and Momentum Topic," *Jurnal Pendidikan IPA Indonesia,* vol. 9, no. 4, pp. 465-476, 2020.

[16] S. Laila and M. Anggaryani, "The Use of STEM-Based Virtual Laboratory (PhET) of Newton’s Law to Improve Students’ Problem Solving Skills," *Jurnal Pendidikan Fisika*, vol. 9, no. 2, p. 125 – 133, 2021.

[17] Sugiyono, Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D, Alfabeta, 2014.

[18] N. Winarno, D. Rusdiana, A. Samsudin, E. Susilowati, N. Ahmad and R. M. A. Afifah, "The Steps of The Engineering Design Process (EDP) in Science Education: A Systematic Literature Review," *Journal for the Education of Gifted Young Scientists,* vol. 8, no. 4, pp. 1345-1360, 2020.

[19] L. Hinyard, E. Toomey, K. Eliot and A. Breitbach, "Student Perceptions of Collaboration Skills in an Interprofessional Context: Development and Initial Validation of the Self-Assessed Collaboration Skills Instrument," *Evaluation & the Health Profssions,* vol. 42, no. 4, pp. 450-472, 2019.

[20] D. E. Meltzer, "The relationship between mathematics preparation and conceptual learning gain in physics: A possible "hidden variable" in diagnostic pre-test scores," *American Association of Physics Teachers,* vol.

70, no. 12, pp. 1259-1268, 2002.

[21] S. Santoso, Complete Guide to SPSS Version 20 Revised Edition, Elex Media Komputindo, 2014.

[22] M. Lelasari, P. Setyosari and S. Ulfa, "Utilization of Social Learning Network in Supporting Student Collaboration Skills," in *TEP & PDs 21st Century Education Transformation*, 2017.

[23] J. Aliyah, "Model Pembelajaran Kooperatif Tipe STAD untuk Meningkatkan Pemahaman Konsep Siswa pada Materi Cahaya," *PENSA*, vol. 4, no. 02, 2016.

[24] P. Sanaghan and J. Lohndorf, "Collaborative Leadership: the New Leadership Stance," in *Higher Ed Impact*, Philadelphia, 2015.

[25] I. W. Redhana, "Menyiapkan Lulusan IPA yang Menguasai Keterampilan Abad XXI," in *UNDIKSHA*, 2019.

[26] H.-J. Han and K.-C. Shim, "Development of An Engineering Design Process-Based Teaching and Learning Model for Scientifically Gifted Students at the Science Education Institute for the Gifted in South Korea," *Asia-Pacific Science Education*, vol. 5, no. 13, pp. 1-18, 2019.

[27] M. Nurtanto, P. Pardjono and S. D. Ramdani, "The effect of STEM-EDP in Professional Learning on Automotive Engineering Competence in Vocational High School," *Journal for the Education of Gifted Young Scientists*, vol. 8, no. 2, pp. 633-649, 2020.

[28] A. N. R. Purnama, N. Winarno, E. C. Prima and N. J. Ahmad, "Fostering Students' Concept Mastery through STEM-Engineering Design Process in Thermal Energy and Heat Transfer Topic," *Integrative Science Education and Teaching Activity Journal*, vol. 4, no. 2, pp. 209-230, 2023.

[29] E. B. Altan and S. Ercan, "Concepts of creativity in design based learning in STEM education," *International Journal of Technology and Design Education*, vol. 31, no. 3, pp. 503-529, 2021.

[30] S. R. Bartholomew, J. Yauney, K. Wolfley and M. Park, "Engineering in Action: Digital Storyboarding as a Way to Integrate Literacy, Engineering, and Technology," *Technology and Engineering Teacher*, vol. 82, no. 2, 2022.

[31] L. Uzel and S. C. Bilici, "Engineering Design-Based Activities: Investigation of Middle School Students' Problem-Solving and Design Skills," *Journal of Turkish Science Education*, vol. 19, no. 1, pp. 163-179, 2022.

[32] N. Mentzer, "High School Engineering and Technology Education Integration through Design Challenges," *Journal of STEM Teacher Education*, vol. 48, no. 2, pp. 103-136, 2011.

[33] N. W. Rati and I. G. Astawan, "How Projects Can Develop Elementary Students' Collaborative Skills," *Journal of Pedagogy and Learning*, vol. 5, no. 3, pp. 534-541, 2022.