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Integrating STEM in Hooke's Law and Elasticity Worksheets: Enhancing Student Collaboration and Learning Outcomes

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Abstract: One of the goals of physics learning is to help students develop collaboration skills. A preliminary study conducted showed that resulting in less than optimal learning outcomes. Such a learning process causes the development of students' collaboration skills to be less stimulated properly. This study aims to determine the effect of web-based worksheets based on STEM integrated problems on students' collaboration skills. The research method uses a quasi-experimental technique with one group pretest-posttest design. The sample was selected using a purposive sampling strategy. The samples involved were 36 students in class F7 of SMA Negeri 1 Kota Jambi. The test was conducted to collect data on students' collaboration skills and student learning outcomes. The research data were collected using a questionnaire of ten questions and a ten-item multiple-choice test that was valid with a reliability coefficient of 0.70. That there was a significant difference between the learning outcomes of students in the pretest and posttest with a sig. (2-tailed) <0.05, which indicates that the STEM-integrated Elasticity and Hooke's Law worksheet has a positive effect on students' critical thinking skills. With an N-Gain score of 0.76 in the high category, the STEM-integrated physics web worksheet on the Elasticity and Hooke's Law material can improve students' collaboration skills.

Keywords: Collaboration skills; Implementation of LKPD; STEM

Introduction

In 21st century education, it is recognized that students need to have creative thinking skills, especially in science learning, so that they can relate the material and concepts taught to solve problems. Therefore, STEM is an appropriate and effective method to be applied in the teaching and learning process (Doyan et al., 2023). One of the learning methods that can improve students' motor skills is STEM. STEM learning integrates two or more disciplines. In STEM classes, students are invited to solve real-world problems and they are actively involved in activities that do not have definite solutions, but must produce clear results through group collaboration (Muyassarah et al., 2019). According to the explanation above, it can be concluded that to solve motor skill problems, students can use a STEM-based learning model.

Using student knowledge to overcome challenges through a science, technology, engineering, and mathematics approach produces students who are skilled in solving every day and academic problems. The STEM approach can be applied in learning materials, for example, Student Worksheets (LKPD). LKPD is a collection of tasks that must be completed by students, usually including instructions or steps to complete the task, which clearly show the basic skills that must be mastered. LKPD is also a tool that supports and facilitates the learning process, allows for productive interactions between students and teachers, and improves student engagement and their learning outcomes (Lubis et al., 2022).

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To face the challenges of the 21st century, the younger generation needs to be equipped with adequate skills and competencies to be able to compete with other countries. One of the essential skills to develop is the ability to work together. To facilitate a collaborative learning process, the ability to collaborate needs to be improved and further deepened (Cholis et al., 2020). Collaborative learning facilitates students to learn together and work together in developing ideas and being responsible for the learning outcomes obtained both individually and in groups (Amania et al., 2019). Collaborative skills are an important aspect of efficient education and are also essential in the world of work. Collaboration involves communication and social interaction where team members work together to solve problems in an active and productive manner (Saenab et al., 2019).

A study conducted by Dewi et al. (2020), entitled "Profile of Student Collaboration Skills in the Mathematics and Natural Sciences Education Cluster" showed that collaborative learning methods are effective for students. Therefore, it is hoped that the application of this learning method can be extended to all levels of education, from elementary school to college, to improve students' collaborative skills and support the improvement of the quality of education.

The results of interviews with physics teachers at SMA Negeri 1 Kota Jambi showed that the school implemented an independent curriculum for grade 11 or phase F. Students have been directed to classes that suit their interests and abilities in studying physics. However, the teaching materials provided do not include Student Worksheets (LKPD) in digital form. In today's digital era, the availability of online LKPD will increase the flexibility and accessibility of education, allowing students to learn anytime and anywhere.

In addition, there is still no physics material related to the STEM (Science, Technology, Engineering, Mathematics) concept. STEM is a very important field of science in the development of technology and science today. Integration of physics with STEM can help students understand the relationship between physics and other fields of science, preparing them for increasingly complex future challenges. Teacher success can be measured by the achievement of learning objectives. LKPD integrated with STEM aims to solve problems in everyday life through school applications. The use of this teaching material is important in an effective teaching and learning process in schools can improve collaboration and learning outcomes. to provide students with new experiences from each (Cholis et al., 2020).

When the teacher gives an explanation in front of the class, students follow carefully. However, students' ability to work together, especially in class F7, is still less effective. This can be seen during the practicum where students prefer to use cellphones rather than following instructions. The reason they use cellphones is that the printed books they have are incomplete. This finding is in line with Nuriyani et al. (2021) which shows that one of the obstacles in implementing the independent curriculum is the difficulty in assessing students and the time needed to make assessment reports. Students' collaboration skills have a direct impact on their learning achievement; the better the collaboration skills, the better the students' learning achievement. Increasing students' skills in working together in groups is directly proportional to increasing their learning achievement.

Related to the statement above, physics is the study of various natural phenomena and is closely related to our daily lives. One of the physics concepts that we know in everyday life is elasticity and Hooke's law. Although this material has been taught in junior high school and students have a basic understanding of elasticity and Hooke's law, many students still have difficulty solving problems related to these concepts (Firdausi et al., 2020). With LKPD, this product can be applied to students during the learning process. Providing a way to do something that affects or influences something is called implementation (Lestari et al., 2014).

Eva Novrianti's previous research in 2022, entitled "Development of Integrated STEM Elasticity and Hooke's Law Student Worksheets with Scaffolding Using the Web" used the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. The research was conducted only up to the small group test stage. Therefore, the researcher is interested in continuing this research at the stage of "Implementation of Integrated STEM Elasticity and Hooke's Law Student Worksheets in Collaboration and Student Learning Outcomes".

Method

The type of research used in this study is experimental. According to Sugiyono (2018), the experimental research method can be interpreted as a research method used to find the effect of certain treatments on others under controlled conditions. Based on this opinion, it can be understood that experimental research is always carried out by giving treatment to research subjects and then seeing the effect of the treatment. The quasi-experimental method is applied using a one-group pretest-posttest design. Quasi-experiments are studies conducted on only one group. There is no control group involved in this study. This design is used because there is a pretest before treatment is given. The results of the treatment can be known more accurately because they can be compared with the conditions before treatment was given. The following is a description of the test design using a one-group pretest-posttest design (Sugiyono, 2018), as in Equation 1.

$$O_1 \; X \; O_2 \quad (1)$$

Information:
O_1 : Pretest
X : Giving treatment (learning with PBL e-modules integrated with STEM)
O_2 : Posttest

The steps of the method in this study are as follows: (1) Compiling a student collaboration skills test instrument. (2) Testing the test instrument before it is used for data collection (validation & reliability). (3) Students are given a pretest by giving a collaboration skills test. (4) Providing treatment to students in the form of implementing a STEM-integrated Elasticity and Hooke's Law physics worksheet developed using a website. (5) Students are given a final test (posttest) by giving a collaboration ability test. (6) Data analysis includes prerequisite tests (normality test, homogeneity test, and paired sample t-test). (7) Conducting an N-Gain test to measure the efficacy of the elasticity and Hooke's Law physics student worksheet in improving students' collaboration abilities.

The sample of this study was 36 students of class F of SMA Negeri 1 Kota Jambi. The sample was selected using a purposive sampling strategy, with the provision that class F students have been taught the basics of Elasticity. Physics learning uses STEM integrated worksheets on the material of Elasticity and Hooke's law. The worksheets are arranged in the form of a website so that they can be accessed by students using a laptop or smartphone.

To collect data on student collaboration skills, questionnaires and tests were given. The test instrument contains a description of ten questions and ten valid multiple-choice questions. The test instrument used has previously been tested on children and is known to have a reliability value of 0.70. Students are given an initial test (pretest) by distributing the collaboration skills test instrument to groups of students, followed by treatment and a final test (posttest) by redistributing the collaboration skills test instrument. The initial test was carried out before leaving the treatment by implementing the LKPD developed using a website integrated with STEM, then continued with the final test.

The normalized N-Gain test was used to measure the efficacy of LKPD in improving students' collaboration skills. Prerequisite tests, such as normality, homogeneity, and T-Sample Test, were conducted before the normalized N-Gain test. The t-sample test was used to determine the effect of collaboration skills on students.

The research hypotheses are as follows:
H_0 : The difference in pretest and posttest scores is significant.
H_1 : There is no significant difference in scores between pretest and posttest.

The H_0 criterion is accepted if only the significance value (p) is below 0.05 ($p<0.05$), and H_0 is rejected if the significance value (p) is above 0.05 ($p>0.05$). The amount of increase in students' collaboration skills is calculated using the N-gain score with the formula in Equation 2:

$$N - Gain\ (g) = \frac{\bar{x} posttest - \bar{x} pretest}{\bar{x} \max - \bar{x}\ pretest} \quad (2)$$

Then the n-gain calculation results are presented using the following criteria as Table 1.

Table 1. N-Gain Calculation Results (Hake, 1998)

Value	Criteria
< 0.7	High
0.7–0.3	Medium
> 0.7	Low

Result and Discussion

To collect data, pretest and posttest on students' critical thinking skills were used. Covers six areas: Positive interdependence, Face to face interaction, Individual accountability and personal responsibility, Communication skills, and Team working skills. Figure 1 presents the results of tests of students' collaboration skills, including the minimum average and maximum values.

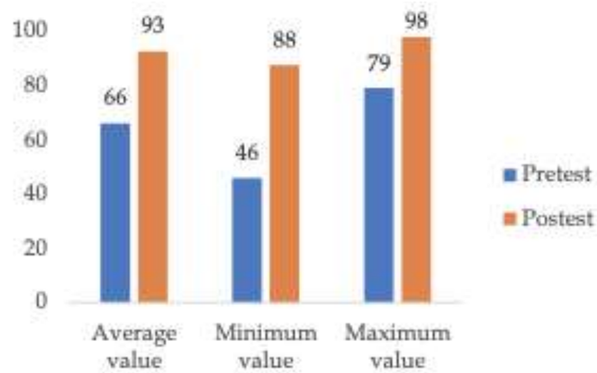

Figure 1. Data on students' collaboration skills test result

Figure 1 illustrates the results of students' collaboration skills test before and after receiving the STEM integrated web-based worksheet. Before being given the worksheet, students obtained pretest results with an average score of 66. The lowest score on the pretest was 46, and the highest score on the pretest was 79. Students obtained an average score of 93 after treatment in learning using the STEM integrated worksheet, with the lowest score of 76 and the highest score of 98. From the results of the critical thinking skills test, students' abilities increased after using the STEM integrated worksheet. The average pretest was 66 and the average posttest was 93 (posttest score > pretest score). This shows that students experienced an increase in collaboration skills.

This improvement in critical thinking skills can be explained by several factors. First, STEM-integrated worksheets are designed to encourage positive interdependence among students, which is an important element in collaborative learning (Johnson et al., 2009). When students feel interdependent, they are more likely to actively participate and contribute to the group, thereby improving their understanding and skills (Slavin, 2010). Second, the face-to-face interactions facilitated by the worksheets allow students to exchange ideas, discuss, and provide feedback to each other (Gillies, 2003). These interactions help students clarify concepts, identify errors, and build deeper understanding (Webb, 2009). Third, the individual accountability and personal responsibility emphasized in the worksheets encourage students to take responsibility for their own learning and their contributions to the group (Cerbin, 2010). This motivates students to study harder and contribute actively to the group (Smith et al., 2005). Fourth, communication skills drilled through worksheets help students to convey their ideas effectively, listen to others, and construct logical arguments (Michaelsen et al., 2008). These skills are essential for critical thinking, as they enable students to analyze information, disseminate evidence, and make informed decisions (Lai, 2011). Fifth, teamwork skills developed through worksheets enable students to work together effectively to achieve common goals (Levi, 2015). These skills are essential for critical thinking, as they enable students to combine different perspectives, solve problems collaboratively, and generate innovative solutions (Hmelo-Silver et al., 2007).

Students' collaboration skills increased after learning using STEM integrated worksheets, as shown in Figure 1. The success of using the researcher-designed worksheets is determined by the increase in students' collaboration skills. To determine the effectiveness of the STEM integrated worksheets, a normalized N-Gain Test was conducted. Prerequisite tests include normality tests, homogeneity tests, and sample T-tests before the normalized N-Gain test was conducted. The significance value obtained from the normality test is managed to interpret the results.

The data is normally distributed after the significance value (p) exceeds 0.05. The homogeneity test is designed to determine data on the collaboration skills of homogeneous variables or vice versa. In the homogeneity test, if the significance value (p) is below 0.05, then the data variance is considered heterogeneous; after the significance value (p) is above 0.05 (p> 0.05), the data variance is declared homogeneous (Setyawan et al., 2020). Table 2 summarizes the scores of students' collaboration skills tests on the pre-test and post-test.

Table 2. Pretest-Posttest Prerequisite Test Values

Conducted test	Significance	Conclusion
Normality (Shapiro-Wilk)	Pre-test = 0.152 Post-test=0.070	Data normally distributed
Homogeneity (Levene's Test)	0.166	Data is homogeneous
Differences of Pretest and Posttest Result (Paired sample t test)	0.000	There is difference between pretest and posttest scores

The prerequisite tests in the form of normality, homogeneity and Paired Sample T-Test were carried out using SPSS 22 software. The normality test was carried out using the Shapiro-Wilk test. This is because the number of samples is less than 50 participants. Based on the results of the normality test, the pretest obtained a significance value (p) of 0.152 and the posttest obtained a value (p) of 0.070 (p>0.05). Because the significance value (p) of both the pretest and posttest is above 0.05, the data on students' collaboration skills can be assumed to be normally distributed. Furthermore, to test homogeneity, this type of Levene test was used. Based on the results of the homogeneity test, the significance value (p) of 0.116 (p>0.05) was obtained, which indicates homogeneous data. Then the Paired Sample T-Test was carried out to determine the indication of the significance of the difference in students' critical thinking skills before and after treatment using the STEM integrated Problem Based Learning electronic module. The results of the Paired Sample T-Test obtained a significance value (p) of 0.000 (p <0.05) which indicates a significant difference in students' critical thinking skills. After the prerequisite test was carried out, a normalized N-Gain test was then carried out to assess the increase in students' learning motivation. The N-Gain value of students' critical thinking skills based on the calculation data showed 0.76 which is included in the high category (Hake, 1998).

In the STEM approach to the PBL learning process, students are directed to open the LKPD and follow the available flow by observing, asking, trying, associating, and communicating a natural phenomenon that is commonly experienced in everyday life. The next step is for students to formulate the problems available in the e-module. Students can develop collaboration skills by identifying possible alternative answers found. In the next stage, students find solutions to a problem and will take steps to solve the problem. The project design stage will hone student collaboration. At the end of the student stage, the teacher guides students to be able to model their mathematical equations on the material being studied. At this stage, students acquire new knowledge by using previously acquired knowledge so that in the learning process, students can solve problems (Budiyono, 2020).

The STEM approach integrated into PBL learning provides a structured framework for students to explore everyday natural phenomena through the stages of observation, questioning, experimentation, association, and communication (Iolanessa et al., 2020). The flow of LKPD and e-modules facilitates problem formulation and the development of collaboration skills in finding alternative solutions (Ahdhianto et al., 2024). Furthermore, project design not only hones collaboration skills but also encourages students to apply prior knowledge in modeling mathematical equations, thereby deepening conceptual understanding and problem-solving skills (Pramasdyasari et al., 2024).

Based on the research results, the integration of web-based LKPD in classroom learning, combined with direct experimental activities, has a positive impact on students' conceptual understanding. Bold discussion sessions through the LKPD web allow students to collaborate and exchange ideas, which is in line with the theory of social constructivism (Vygotsky, 1978). Meanwhile, direct experimental activities provide empirical experiences that strengthen their conceptual understanding (Piaget, 1972). The combination of these two approaches has proven effective in increasing student engagement and learning outcomes. Further research can explore the effectiveness of this learning model on different topics or using more sophisticated technology.

Learning that integrates web-based LKPD discussions and direct experiments provides a comprehensive learning experience for students. Online discussion sessions through web LKPD allow students to analyze concepts and formulate hypotheses, which are then tested through practical experimental activities (Putri et al., 2024). Learning that combines web-based LKPD discussions and direct experiments provides a comprehensive learning experience for students. Online discussion sessions through web LKPD allow students to analyze concepts and formulate hypotheses, which are then tested through practical experimental activities (Cristina et al., 2014). This integration helps students link theory to practice, deepen their understanding of concepts, and develop critical thinking and problem-solving skills. This combination not only improves conceptual understanding, but also students' scientific skills in designing, implementing, and evaluating experiments (Auliya et al., 2023). The application of this method also encourages collaboration and communication between students, because they have to discuss and share their findings both online and while conducting experiments (M. P. Sari et al., 2018).

In this study, learning was carried out in class by opening the web LKPD for discussion, while experimental or trial activities were carried out directly. The following is a description of the learning and practicum activities in this study.

Figure 2. Learning activities in LKPD integrated STEM website

Figure 3. Experiment practicum activities at LKPD integrated STEM website

The researcher's LKPD contains sample questions for each sub-material and an evaluation at the end of the learning process (final learning assessment). The evaluation has two sub-evaluations, namely cognitive evaluation and collaboration skills evaluation. The presentation of practice questions is intended so that students can measure their abilities during the learning process so that students can evaluate their strengths and weaknesses in studying the sub-material. Evaluations carried out by students on themselves can help students develop themselves to be better at learning and foster student initiative to try better in each learning. The presentation of evaluation questions is intended so that students can measure their abilities after receiving lessons from the teacher so that students can conduct self-evaluations after completing a material or chapter.

STEM-integrated LKPD also contains problems in life according to the material on the characteristics of mechanical waves. LKPD integrated with STEM invites students to take part in various problem-solving activities, such as learning videos, simple practices, or simulation-based practices followed by discussions. This stage can stimulate students' minds to be more active. Students are encouraged to seek information with their minds through simple practices or practices using simulations rather than being given information directly by the teacher. The learning process continues with the assessment stage, namely students are given various questions to answer. This stage encourages students to collaborate and think critically in solving and responding to problems. In addition, the problem-solving steps are guided by the syntax of STEM-integrated Problem Based Learning. PBL is the entire learning to generate problem-solving thinking, starting from the beginning of learning synthesized and organized into a problem so that it can accustom students to understand concepts by constructing their knowledge (Kurniati et al., 2021). Learning with the STEM-integrated Problem Based Learning model makes students more active because learning is based on real-life problems, so that learning is not abstract and is more relevant to students' lives. In addition, the STEM-integrated problem-based learning model is a learning model that can help students in conceptual maturation because students are asked to find solutions by using thinking skills and gathering information through discussions and practical activities (Cherian et al., 2012). In the STEM-integrated problem-based learning process, students must produce work in each learning cycle. The work is an implementation of the engineering aspect; In the engineering aspect, students are asked to apply the knowledge they have acquired into a design or work.

Based on the results of the pretest and posttest assessments, students' collaboration skill scores increased in the high N gain category by 0.76. Research Roektiningroem et al. (2018) states that the STEM-integrated Problem Based Learning model can improve critical thinking skills and cognitive learning outcomes. The STEM-integrated problem-based learning model can improve students' critical thinking skills, as shown by the results of the N-gain and t-test. The independent sample t-test showed a significant difference between the critical thinking skills of the control group and the experimental group, while based on the paired sample t-test, the sig. (2-tailed) <0.05, which indicates that the STEM-integrated problem-based learning model has a positive effect on students' critical thinking skills (Ariyatun et al., 2020). The PBL learning model combined with STEM can improve students' critical thinking skills on average. By integrating STEM into the learning model, learning will be more meaningful, especially related to students' daily problems. Through STEM-integrated PBL learning, students are challenged to collaborate and be creative and innovate to solve existing problems through teamwork. Research conducted by Putri et al. (2024) to measure the improvement of students' collaboration skills with the results of the STEM-integrated PBL model can improve the collaboration skills of high school students. This assessment stage is related to learning evaluation. At this stage, both during the learning process and at the end of learning, learning evaluation must be carried out. STEM-integrated problem-based learning is carried out by presenting problems and questions, facilitating investigations, opening dialogue with students, and actualizing students' environmental literacy and creativity (Mulyana et al., 2018). At the learning stage, STEM-integrated problem-based learning allows for elaboration, collaboration, and collaborative interaction of students in analyzing problems and the reporting process. Through STEM-integrated problem-based learning, students demonstrate positive attitudes, achieve integrated conceptual and procedural knowledge, and demonstrate active behavioral intentions (Lou et al., 2011). Implementing STEM-based learning requires changing the learning model from teacher-centred to student-centred learningand individual learning to collaborative learning, emphasizing creativity and problem-solving in applying scientific knowledge (Doyan et al., 2023).

Figure 4. Students' activities to apply LKPD integration STEM website

Student worksheets (LKS) integrated with the STEM approach have been proven effective in increasing student engagement in the learning process. This is in line with research showing that contextual and real-life relevant learning, such as that offered by STEM, can increase student motivation and interest (Y. Sari et al., 2013). In addition, STEM LKS also encourages students to be active in solving problems, which in their pairs can strengthen their collaboration skills (Rahayu et al., 2021). These collaboration skills are very important in the 21st century, where students are required to be able to work together in time to achieve common goals (Kemendikbud, 2017).

STEM-integrated student worksheets can attract students' attention and make them more active during learning. Students' willingness to solve the difficulties and problems presented can have a positive impact on their collaboration skills (Hamidah et al., 2022).

STEM education plays an important role in improving students' critical thinking skills, problem solving, and creativity in dealing with real-world problems (Li et al., 2020). STEM education also encourages the integration of various disciplines, so that students can understand concepts more holistically and apply them in various contexts (English, 2016). In addition, STEM-based learning with an inquiry approach can increase students' engagement, motivation, and scientific literacy, which ultimately prepares them to face career challenges in the STEM field (Kelley et al., 2016). Not only that, but hands-on STEM activities also contribute to the development of collaboration and communication skills, which are important competencies in the 21st century workforce (Bybee, 2013).

Conclusion

Based on the research results, STEM integrated elasticity and hooke's law worksheets can improve students' collaboration skills, as indicated by the N-gain results. Before the N-gain test was conducted, normality, homogeneity, and t-tests were first conducted. In the normality test, the data were normally distributed. In the homogeneity test, the data were homogeneous. Based on the paired sample t-test, it showed that there was a significant difference between pretest and posttest collaboration skills with a sig. (2-tailed) <0.05, which indicates that STEM integrated elasticity and hooke's law worksheets have a positive effect on students' collaboration skills. With an N-Gain score of 0.76 in the high category, STEM integrated worksheets on elasticity and hooke's law can improve students' collaboration skills.

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Author Contributions

WSS: writing-original draft preparation, result, discussion, methodology, conclusion; DPR and MH analysis, proofreading, review, and editing.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the Publication of this paper.

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