Journal of Education and e-Learning Research
Vol. 10, No. 2, 314-322, 2023
ISSN(E) 2410-9991 / ISSN(P) 2518-0169
DOI: 10.20448/jeelr.v10i2.4617

Development of an inquiry-based module with scientific equipment to facilitate primary school students learning the force concept

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Abstract

Recently, science, technology, engineering and mathematics (STEM) applications have become more demanding, promoting students' interest in science from an early age. Science class in primary school needs more attention to attract students' interest. This study aims to develop an inquiry- based module with scientific equipment for the primary school level to optimize science learning at the primary school level. The development process used a 4-D (define, design, develop and disseminate) model. The developed module and equipment cover the topics of forces and include four experiments, i.e., exploring friction in inclined planes, exploring the mechanical advantage of a pulley, observing magnetic force and exploring static equilibrium in a lever. The modules and scientific equipment are distributed to some schools in Indonesia that lack practical work facilities. The inquiry-based modules and scientific equipment are implemented in classes at four primary schools in Indonesia. In this study, the students' response to the implementation of inquiry-based modules and scientific equipment in the class is also investigated. Overall, the average of the students' responses is 3.37 (out of 4.00). It means students respond positively to the learning activity and the supporting module. Active learning with an inquiry approach is feasible to attract students' interest in science.

Keywords: Inquiry, Module, Primary school, Science kits.

Contents

Citation | Herwinarso, Koswojo, J., & Pratidhina, E. (2023). Development of an inquiry-based module with scientific equipment to facilitate primary school students learning the force concept. *Journal of Education and E-Learning Research, 10*(2), 314-322. 10.20448/jeelr.v10i2.4617
History:
Received: 17 October 2022
Revised: 24 February 2023
Accepted: 30 March 2023
Published: 28 April 2023

Publisher: Asian Online Journal Publishing Group

Funding: This research is supported by the Indonesian Ministry of Education, Culture, Research, and Technology through the PTUPT research grant (Grant numbers: 001/AMD-SE2H/IJT-MUIJTI-PDK/LL7/2021 and 003/SP2H/PT-L/LL7/2022).
Authors' Contributions: All authors contributed equally to the conception and design of the study.
Competing Interests: The authors declare that they have no conflict of interest.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study followed all ethical practices during writing.

Contribution of this paper to the literature
This research contributes to the existing literature on inquiry-based learning at the primary school level. This study also contributes to solve the lack of science learning media at primary schools in Indonesia. This paper explains how to implement inquiry-based learning with scientific equipment in class which has received positive responses from students.

1. Introduction

STEM (science, technology, engineering, and mathematics) applications in daily life have increased rapidly. From an early age, students should be introduced to science. In primary school, science education becomes important to engage children in the STEM field (Barakat, 2022; Rogosic et al., 2021). Science education has also contributed to enhance scientific thinking among primary school students. In science class, students are involved in observation or experiment preparation, measurement, procedure evaluation, evidence examination and data analysis. TIMSS (2015) mentioned some goals of science education at the primary level. They include developing curiosity and interest in science, developing problem-solving ability, acquiring basic scientific knowledge and concepts, recognizing science's benefits and limitations, knowing the interconnections among science, technology and society and developing responsibility including respect for the environment.

Students need to have experience observing scientific phenomena and conducting simple experiments to acquire scientific knowledge and concepts. Hence, an activity-based approach can be implemented. Practical work in science education has several advantages: students can learn the nature of science, scientific methods and scientific concepts (Löfgren, Schoultz, Hultman, & Björklund, 2013). Students learn about the phenomenon through practical work (John & Paulsen, 1999). Observations and descriptions in practical work may stimulate logical reasoning (Watson, 2000).

Involving students in the scientific inquiry process is suggested since it helps them acquire scientific concepts (Caiman & Jakobson, 2019). It is necessary to provide opportunities for students to discover science instead of just receiving direct information from teachers (Kalyon, 2020). Students' process skills can also be developed through inquiry-based learning (Ergül et al., 2011; Mulyeni, Jamaris, & Suprjyati, 2019).

Science learning should be enjoyable for students (Anggoro, Sopandi, & Sholehuddin, 2017) to improve their interest and passion in science. Using only traditional methods of teaching is no longer relevant for students nowadays (Kola & Kola, 2013; Narayan, 2016). Students should be involved in exciting activities. Some studies show that practical science activities can create excitement in the learning process and increase students' attitudes towards the science learning process (Sadi & Cakiroglu, 2011; Toma & Greca, 2018). Moreover, research shows that inquiry-based learning stimulates an interest in science in primary school students (Spencer & Walker, 2011).

According to the Programme for International Student Assessment (PISA), students in Indonesia have low science skills. Many factors may contribute to the low level of science skills among Indonesian students. In many schools, science is only presented by teachers through lectures. Hence, students lack experience exploring scientific phenomena directly. Many primary schools have no appropriate science learning media.

The main challenge is to provide resources that facilitate active science learning in primary schools that lack learning resources. To address the issue, active-based learning has been developed with scientific equipment appropriate for the primary school level and distributed to some schools. The distributed scientific equipment will support teachers in implementing inquiry-based activities and make science learning more enjoyable for students. The scientific equipment accompanied by the modules aims to guide students in exploring scientific phenomena. The following are the objectives of the study:

(1) Creating the scientific equipment and the learning modules.
(2) Implementing the scientific equipment and the learning modules in a science class at a primary school within an inquiry-based learning model.
(3) Investigating the students' views on the use of scientific equipment and learning modules in the class.

2. Literature Review

2.1. Inquiry-Based Learning

Inquiry-based learning is a learning strategy that stimulates students to be active in the learning process (Ernst, Hodge, & Yoshinobu, 2017; Unlu & Dokme, 2020). In inquiry-based learning, students are involved in activities that follow scientific methods and practices when establishing knowledge. The activities stimulate students to discover new causal relations through hypothesis formulation, experimentation or observations (Pedaste, Mäeots, Leijen, & Sarapuu, 2012). In some studies, inquiry-based learning often includes applying several problem-solving skills (Song, Cao, Yang, & Looi, 2022; Yuliati, Riantoni, & Mufti, 2018). In inquiry-based learning, each student is the main actor who discovers new knowledge. Inquiry-based learning has main features such as: (1) students are engaged in discussions, (2) students suggest and search for evidence, (3) students construct arguments according to what they observe, (4) students connect their arguments to theories and (5) students communicate the result (Khalaf & Zin, 2018).

The inquiry-based method contributes to provide a supportive explanation of natural phenomena. There are some rationales for implementing inquiry-based learning in the classroom such as: (1) it stimulates the improvement of students' behaviors and skills, (2) it engages students in reading, writing and participating in critical discussions and (3) it encourages them to participate in presenting critical arguments (Khalaf & Zin, 2018). The effectiveness of inquiry-based learning has been shown in some studies. Inquiry-based learning can enhance students' critical thinking skills (Duran & Dökme, 2016; Prayogi, Yuanita, & Wasis, 2018; Thaiposri & Wannapiroon, 2015) and it promotes scientific literacy (Wen et al., 2020).

The implementation of inquiry-based learning requires more effort compared to the traditional method. Teachers should define for students the new knowledge. Teachers should also plan activities that stimulate students to achieve their learning goals. During the learning process, teachers are facilitators who motivate students to discover new knowledge. Teachers should understand the nature of science to prepare lesson plans that focus on the content's quality (Eltanahy & Forawi, 2019).

In the constructivist view, students' conceptions change through participation in inquiry-based learning. Hence, inquiry-based learning is appropriate for developing students' conceptual understanding (Laksana, Dasna, & Degeng, 2019). Some variations of the inquiry model can be implemented in the classroom such as free inquiry, guided inquiry or modified inquiry (Spencer & Walker, 2011). The guided inquiry is considered the most suitable for the primary school level.

Inquiry-based learning is flexible and can be done through a variety of learning phases. Although there is variation in the learning phases of the inquiry framework. In general, inquiry-based learning phases include orientation, conceptualization investigation, conclusion and discussion (Pedaste et al., 2015). The initial phase is an orientation that aims to get the students started with a new topic to be investigated. Other terminologies such as 'introduction to a topic,' 'learning challenge,' and 'engage' are used instead of orientation. After orientation, the learning process continued with students being asked more scientific questions about a specific domain. This activity is usually called questioning. It is followed by hypothesis generation in which students must make a hypothesis or prediction before preparing an investigation or exploration. Sometimes hypothesis generation overlaps with questioning. It is considered one inquiry phase called conceptualization.

An investigation follows the conceptualization. Investigation can be exploration or experimentation. Exploration is more related to a simple observation process. Meanwhile, the experiment is more related to searching for evidence concerning a hypothesis. Investigation can include some activities such as planning, observation, data interpretation and analysis. Based on the investigation results, students draw conclusion. Finally, the discussion is conducted. In discussion, students present their findings by communicating with others. Reflection can also be included in the discussion phase. Within the phases of the inquiry-based learning model, students will be actively involved in the learning process that stimulates their interest in learning science.

2.2. Learning Media

Learning media or technologies can be viewed as tools to support teaching and learning. They facilitate students participation in meaningful experiences during the learning process and attract students' interest (Nurpratiwiningsih & Setiyoko, 2018). Learning media have several roles such as: (1) presenting information clearly, (2) overcoming the limitations of space, time and sense-power, (3) stimulating students to be active in the learning process and (4) motivating students to learn (Puspitarini & Hanif, 2019). There are many kinds of media, e.g., text, graphics, audio, video, computing and demonstration or experimental tools that can assist students in learning in various ways and achieve different learning goals.

Students' and materials characteristics must be addressed while selecting a learning medium. The characteristics of students in primary school are different from those of older students. According to Piaget's theory of cognitive development, students in primary school can generally be considered young learners (age 7-11 years) who have acquired the ability to think logically but only about concrete objects. Students in primary school still face difficulties thinking about abstract things. According to such characteristics, learning media that show a concrete phenomenon can facilitate primary school students (Laksana et al., 2019).

The implementation of inquiry-based learning involves practical activities in which students investigate a real phenomenon. High-quality and practical activities also improve students' interest in learning science (Holstermann, Grube, & Bögeholz, 2010). Practical activities provide a more realistic and exciting experience for students. Learning instruments and materials should be prepared to facilitate practical activities in science class.

Active engagement has become one of the main focuses of primary school science learning. Educational media have a significant role in influencing the dynamic learning process. The use of educational media engages students in the scientific thinking process because learning media can help describe concrete phenomena. Scientific equipment can serve as an ideal learning medium to support the implementation of inquiry-based learning in primary schools (Dewi, Mairizwan, Afrizon, & Hidayati, 2021; Slavin, Lake, Hanley, & Thurston, 2014). It can help science teachers prepare for science learning within an inquiry environment. Using scientific equipment as a learning medium can build a more active, effective and joyful science learning situation (Atun & Latupeirisa, 2021).

3. Method

3.1. Research Design and Procedure

This study uses a research and development (R&D) design. The 4D model which consists of the define, design, develop and disseminate phases (Thiagarajan, Sammel, & Melvyn, 1974) is used as a development model. Figure 1 illustrates the steps in each stage. This study aims to develop a science learning media kit for the primary level accompanied by an appropriate activity-based module.

3.1.1. Define Phase

The define phase involves a need assessment conducted at four primary schools in East Java, Central Java and Yogyakarta Province, Indonesia. Based on the evaluation, we found that the schools need scientific equipment for the topic of force. The topics are taken as the scope of media kit development. We also had focus group discussions with some primary school teachers about the curriculum implemented at their schools.

3.1.2. Design Phase

According to the needs and curriculum analysis done in the define stage, we design the media kits and modules. We develop modules with an emphasis on developing the students' scientific skills. Hence, the module is designed within the inquiry approach.

3.1.3. Develop Phase

The media and module prototypes are evaluated through brainstorming with experts and teachers in the development stage. An improvement in the media kit's appearance was based on advice from teachers and experts.

The accompanying modules are also revised to align with the scientific approach and STEM integration appropriate for the primary level.

3.1.4. Disseminate Phase

The final product of media kits and accompanying modules are packed and distributed to some primary schools in Indonesia. Teachers in collaborating schools were trained to use the scientific equipment as media within the scientific approach. Then, they implement it in their class. After implementation, students' responses are gathered through questionnaires.

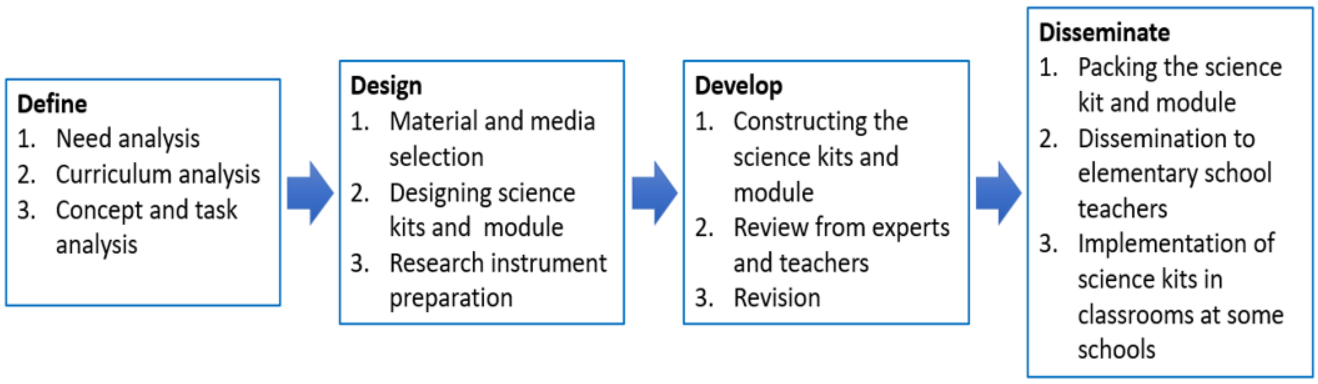


Figure 1. The steps in the 4-D model that is employed in this study.

3.2. Data Collection and Analysis

The instruments used in this research consist of interview guides, validation checklists and students' response questionnaires. Interview guides are used to collect information for analysis. During the prototype development stage, feedback from experts and teachers are collected through interviews and a validation checklist. After the science media kits and the module are implemented at schools, the students' feedback is collected with their response questionnaires. The students' answers to each item in the questionnaire are converted into quantitative data such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3 and "strongly agree" = 4. The quantitative data are analyzed with descriptive statistics and interpreted into categories as shown in Table 1. The category is constructed using the ideal mean score (X_i) and ideal standard deviation (SDi) as a basis (Widoyoko, 2016; Wirjawan, Pratama, Pratidhina, Wijaya, & Untung, 2020).

Table 1. Classification of the actual average score of students' response.

No	Score interval formula	Score interval	Criteria
1	$\bar{X} > \bar{X}_i + 1.8SDi$	$\bar{X} > 3.4$	Very good
2	$\bar{X}_i + 0.6SDi < \bar{X} \leq \bar{X}_i + 1.8SDi$	$2.8 < \bar{X} < 3.4$	Good
3	$\bar{X}_i - 0.6SDi < \bar{X} \leq \bar{X}_i + 0.6SDi$	$2.2 < \bar{X} < 2.8$	Acceptable
4	$\bar{X}_i - 1.8SDi < \bar{X} \leq \bar{X}_i - 0.6SDi$	$1.6 < \bar{X} < 2.2$	Poor
5	$\bar{X} \leq \bar{X}_i - 1.8SDi$	$\bar{X} \leq 1.6$	Very poor

3.3. Participants

Four primary schools are collaborating in the dissemination stage. Those schools are in East Java, Central Java and Yogyakarta Province, Indonesia. 119 students participated in the implementation process.

4. Results and Discussions

4.1. The Features of the Module and Science Kit

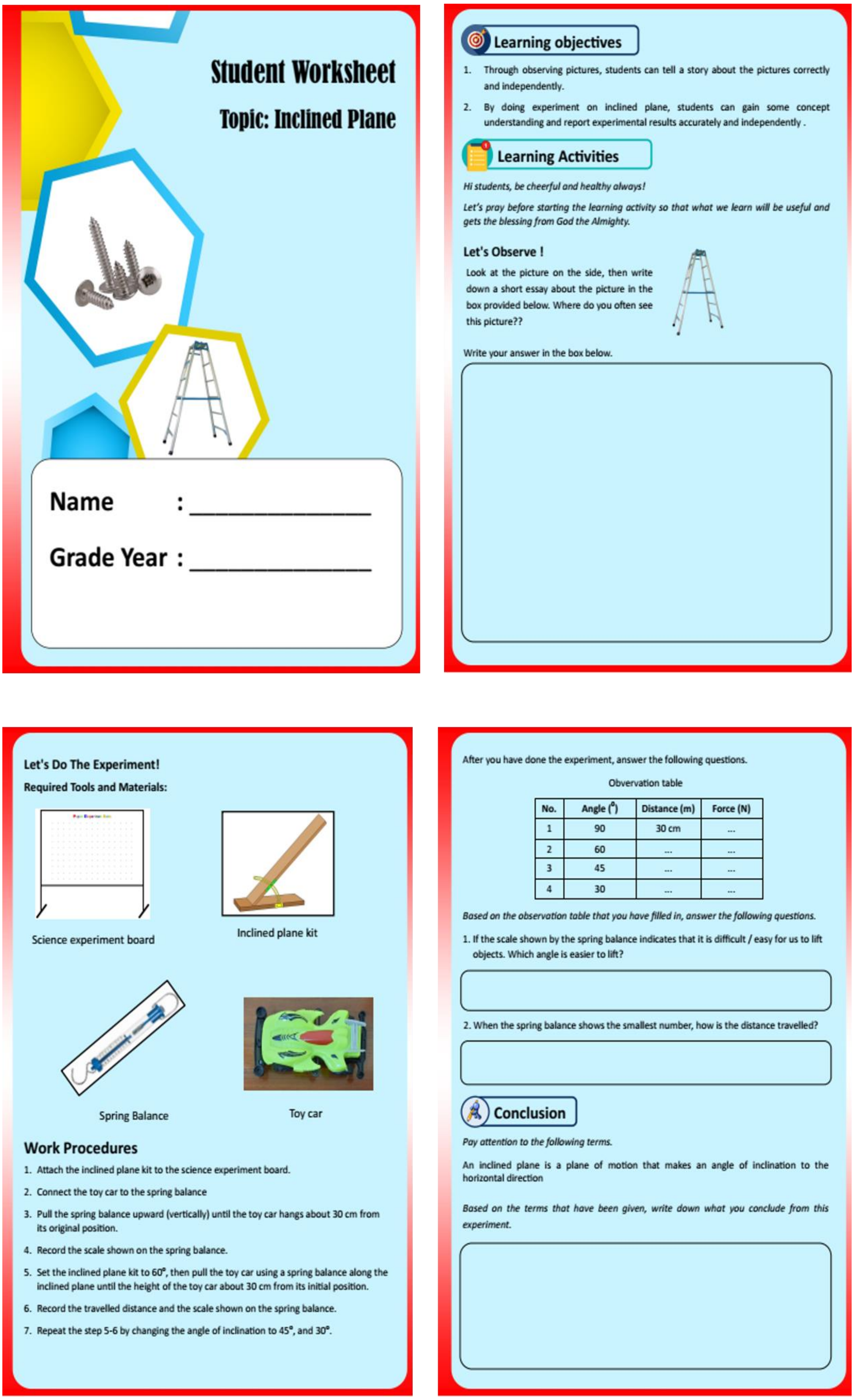
The module covers force topics and is presented within the inquiry approach. Each module has components such as a title page, learning objective, learning activities, conclusion reading material, reflection and test as depicted in Figure 2. The learning activities section guides students to explore scientific phenomena and discover new concepts using scientific equipment. The activities start with observation as a stimulus for orientation and conceptualization. After that, it is followed by an experiment, elaboration and conclusion. The module also includes reading material for enrichment. In the last part, students are asked to reflect on their learning activities.

Four scientific equipments are produced as learning media, i.e., the inclined plane, lever, pulley and magnetic force kits presented in Table 2. The inclined plane kits can be seen in Figure 3. This kit is used as a medium to facilitate students' understanding of friction and the factors influencing its magnitude.

The lever kit facilitates students' exploration of static equilibrium conditions. Figure 4 illustrates the components of lever kits. With the lever kits, students can identify the force arms, turning point, force and their effects on the static equilibrium state. Students can also recognize that a force has a magnitude and a direction.

Figure 5 illustrates the components of pulley kits. The pulley kit facilitates students' understanding of the role of simple machines. The simple machine can minimize the force required to do some work. Students can also explore the concept of mechanical advantage. Students can also distinguish the different types of pulleys with a more significant mechanical advantage.

We also developed a magnetic force kit that facilitates students' recognition of magnet properties. The components of the magnetic force kit can be seen in Figure 6. Students can observe the magnetic force exerted by a magnet. Moreover, students also explore how heat affects magnetic properties.



Student Worksheet

Topic: Inclined Plane

Name :

Grade Year :

Learning objectives

1. Through observing pictures, students can tell a story about the pictures correctly and independently.
2. By doing experiment on inclined plane, students can gain some concept understanding and report experimental results accurately and independently .

Learning Activities

Hi students, be cheerful and healthy always!

Let's pray before starting the learning activity so that what we learn will be useful and gets the blessing from God the Almighty.

Let's Observe !

Look at the picture on the side, then write down a short essay about the picture in the box provided below. Where do you often see this picture??

Write your answer in the box below.

Let's Do The Experiment!

Required Tools and Materials:

Science experiment board

Inclined plane kit

Spring Balance

Toy car

Work Procedures

1. Attach the inclined plane kit to the science experiment board.
2. Connect the toy car to the spring balance
3. Pull the spring balance upward (vertically) until the toy car hangs about 30 cm from its original position.
4. Record the scale shown on the spring balance.
5. Set the inclined plane kit to 60°, then pull the toy car using a spring balance along the inclined plane until the height of the toy car about 30 cm from its initial position.
6. Record the travelled distance and the scale shown on the spring balance.
7. Repeat the step 5-6 by changing the angle of inclination to 45°, and 30°.

After you have done the experiment, answer the following questions.

Observation table

No.	Angle (°)	Distance (m)	Force (N)
1	90	30 cm	...
2	60	...	...
3	45	...	...
4	30	...	...

Based on the observation table that you have filled in, answer the following questions.

1. If the scale shown by the spring balance indicates that it is difficult / easy for us to lift objects. Which angle is easier to lift?
2. When the spring balance shows the smallest number, how is the distance travelled?

Conclusion

Pay attention to the following terms.

An inclined plane is a plane of motion that makes an angle of inclination to the horizontal direction

Based on the terms that have been given, write down what you conclude from this experiment.

Figure 2. Sample of the module.

Table 2. The science kit description.

<table>
<tr><th>Science kit</th><th>Activity objectives</th></tr>
<tr><td>
Inclined plane

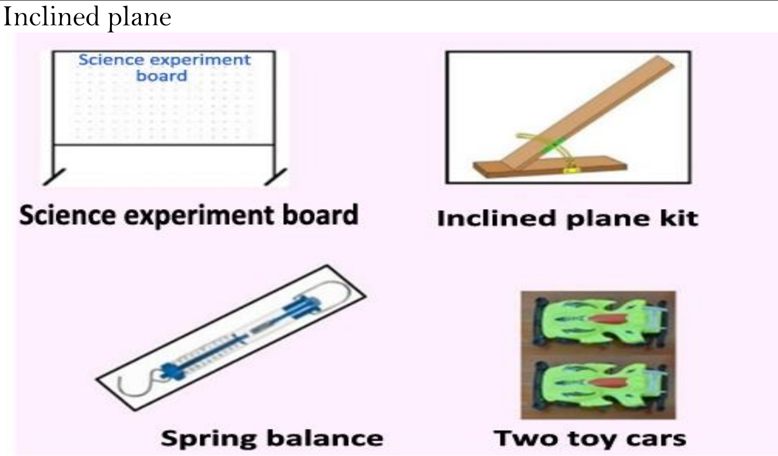


Figure 3. Components of inclined plane kit.
</td><td>
Students can identify:

1. Friction is a force that holds an object so that it does not move even if it is pulled.
2. Friction occurs when two objects are in contact with each other.
3. Wheels serve to reduce friction.
4. The magnitude of the frictional force depends on the state of the surfaces in contact with each other. The friction on a smooth surface is less than on a rough surface.
5. The magnitude of the frictional force also depends on the weight of the rubbing object.
</td></tr>
<tr><td>
Lever

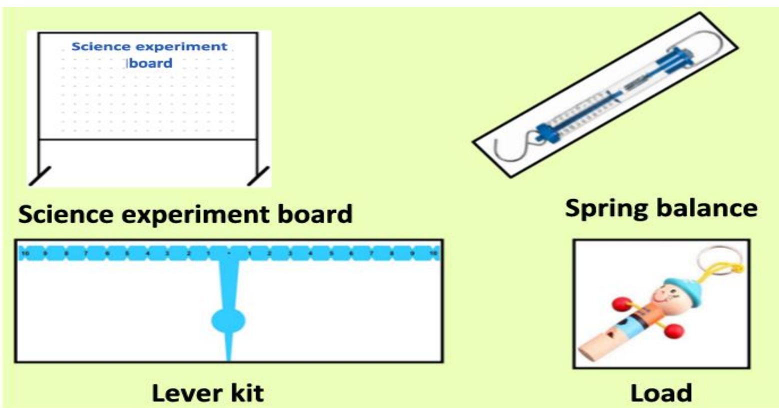


Figure 4. Components of lever kit.
</td><td>
Students can explore that:

1. The shorter the distance of the right arm from the turning point, the greater the force required.
2. The shorter the distance of the force arm (Power) from the center point, the greater the force required.
</td></tr>
<tr><td>
Pulley

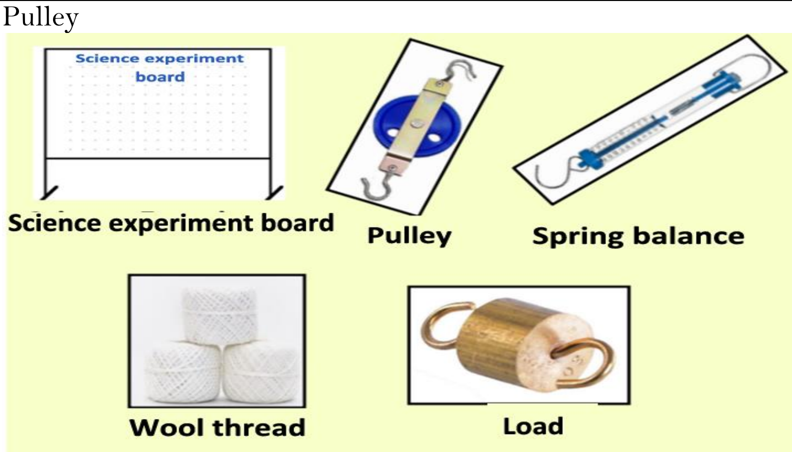


Figure 5. Components of pulley kit.
</td><td>
Students can find out that:

1. The pulley makes it easier for people to move or lift objects.
2. The more pieces of thread in the pulley system, the less force is needed to lift the object.
</td></tr>
<tr><td>
Magnetic force

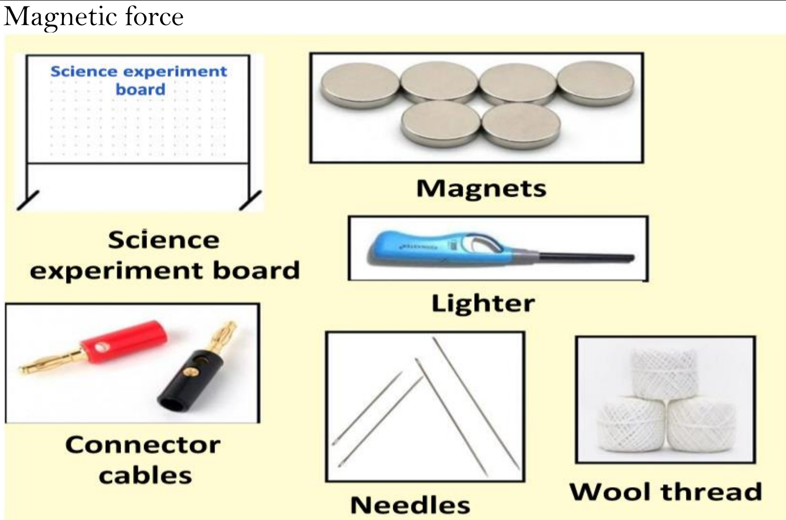


Figure 6. Components of magnetic force kit.
</td><td>
Students can identify that:

1. A magnet can attract an object made of steel or iron.
2. The magnetic properties can be removed when it is heated.
</td></tr>
</table>

4.2. The Implementation of the Module and Science Kit

The module and the scientific equipment are implemented in the class within an inquiry-based learning model. The learning phase includes orientation, conceptualization, investigation, conclusion and discussion. The description of each phase is presented in Table 3.

Table 3. Learning phase.

Phase	Description
1. Orientation	Students are introduced to the topics, i.e., force concepts by being asked to observe phenomena around them such as the movement of an object.
2. Conceptualization	Students are encouraged to raise a question about what they have observed. They were also asked to make a prediction.
3. Investigation	Students conducted investigations by experimenting with or exploring the scientific equipment delivered to them. The investigation was guided by a worksheet and facilitated by the teachers. Students actively set up the scientific equipment, collect, analyze and present the data.
4. Conclusion	Students draw a conclusion based on the results of the investigation.
5. Discussion	Students communicate their results to the class. The teacher elaborates on the students' ideas and gives reinforcement. Students also reflected on the activities that they had conducted.

After the learning activities using the module and scientific equipment students are asked to fill out a questionnaire with five Likert scale questions. One hundred nineteen (119) students filled out the questionnaire appropriately. The survey aims to know the students' views on the module and the inquiry- based learning activities using the scientific equipment. The summary of students' responses is presented in Table 4. The overall mean score is 3.37 which can be categorized as very good.

Table 4. The students response to the module and experiment activity with the scientific equipments .

No	Statements	Strongly disagree (1)	Disagree (2)	Agree (3)	Strongly agree (4)	Mean score	Standard deviation
1	The module explains all the equipment required for the experiment.	0 (0%)	0 (0%)	75 (63 %)	44 (37%)	3.37	0.48
2	The procedures for experiments are explained correctly and clearly.	0 (0%)	0 (0%)	58 (49%)	61 (51%)	3.51	0.50
3	The font and visualization in the module are well arranged.	0 (0%)	0 (0%)	79 (66%)	40 (34%)	3.34	0.47
4	The information in the module is easy to understand.	0 (0%)	0 (0%)	71 (60%)	48 (40%)	3.40	0.49
5	The figures on the module are suitable for the written instruction.	0 (0%)	0 (0%)	77 (65%)	42 (35%)	3.35	0.48
6	The module helps me conduct the experiments.	0 (0%)	0 (0%)	88 (74%)	31 (26%)	3.26	0.44
7	The activities in the module help me understand the science concepts.	0 (0%)	0 (0%)	76 (64%)	43 (36%)	3.36	0.48
8	The design of the module is interesting.	0 (0%)	0 (0%)	80 (67%)	39 (33%)	3.33	0.47
Overall mean score						3.37	

Students give positive responses to the quality of the module. They agree that the module explains the experiment equipment and the procedure clearly. 40 % of students strongly agree and 60 % agree that the information in the module is easy. In addition, students also think that the layout of the module is well-designed. 33% strongly agree that the module design was attractive while the rest agree.

The experiment using the scientific equipment and the guidance provided in the module help students understand the science concept. 64% of students agree and 36% strongly agree with this statement. Students' positive views on implementing inquiry-based activities in this study align with a study conducted by Massaro et al. (2022) and Pavan et al. (2021). Practical work changes interest in science in a positive direction among primary school students. In addition, laboratory work improves the participation of students. Students directly conduct exploration, hypothesis testing, data collection, analysis and explanations based on the empirical evidence found. The activities undertaken by the students stimulate them to acquire more meaning from the learning process (Laksana et al., 2019). It potentially helps students construct their cognitive structure.

The school implemented a school-from-home program before inquiry-based learning was conducted. During the school-from-home program, most students learn from the books and explanations provided by teachers through video conferences. There were some exploration activities at home. However, not all students have access to appropriate facilities at home. Therefore, students are excited and motivated during the science kit's inquiry-based learning activities. The learning activities provide a playful atmosphere yet students are stimulated to think critically.

5. Conclusion

In this study, we have developed a set of science experiment kits and the accompanying modules that cover topics of force at the primary level. The scientific equipment has been implemented in four primary schools in Indonesia to support inquiry-based learning activities. Students responded positively to the inquiry-based learning activity and the use of the module. The study has some limitations. This study only measures students' views on the module, scientific equipment and activity. We have not explored how using scientific equipment in inquiry-based activities affects students' conceptual understanding and scientific skills. Those issues will be considered in future work to widen the scope of the science topics to include more than just force.

References

Anggoro, S., Sopandi, W., & Sholehuddin, M. (2017). Influence of Joyful learning on elementary school students' attitudes toward science. *Journal of Physics: Conference Series*, *812*(1), 012001. https://doi.org/10.1088/1742-6596/755/1/011001

Atun, S., & Latupeirisa, V. P. S. (2021). Science KIT teaching aid for the Earthquake in improving students' collaboration skills and creative thinking in Junior High School. *European Journal of Educational Research, 10*(1), 187-197. https://doi.org/10.12973/EU-JER.10.1.187

Barakat, R. (2022). Science and representation: Examining the role of supplementary STEM education in elementary school student science identity. *SN Social Sciences, 2*(3), 1-19. https://doi.org/10.1007/s43545-022-00327-6

Caiman, C., & Jakobson, B. (2019). The role of art practice in elementary school science. *Science & Education, 28*, 153-175. https://doi.org/10.1007/s11191-019-00036-2

Dewi, W. S., Mairizwan, M., Afrizon, R., & Hidayati, H. (2021). The improvement of the competency of science teachers using science KIT: Optimizing scientific learning. *Indonesian Journal of Science and Mathematics Education, 4*(1), 89-98. https://doi.org/10.24042/ijsme.v4i1.7956

Duran, M., & Dökme, İ. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(12), 2887–2908. https://doi.org/10.12973/eurasia.2016.02311a

Eltanahy, M., & Forawi, S. (2019). Science teachers' and students' perceptions of the implementation of inquiry-based learning instruction in a Middle School in Dubai. *Journal of Education, 199*(1), 13–23. https://doi.org/10.1177/0022057419835791

Ergül, R., Şımşeklı, Y., Çaliş, S., Özdılek, Z., Göçmençelebı, S., & Şanli, M. (2011). The effects of inquiry-based science teaching on elementary school students' science process skills and science attitudes. *Bulgarian Journal of Science and Education Policy, 5*(1), 48–69.

Ernst, D. C., Hodge, A., & Yoshinobu, S. (2017). What Is inquiry-based learning? *Notices of the American Mathematical Society, 64*(06), 570–574. https://doi.org/10.1090/noti1536

Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education, 40*(5), 743–757. https://doi.org/10.1007/s11165-009-9142-0

John, L., & Paulsen, A. C. (1999). Practical work in science education: Recent research studies. *Studies in Science Education, 33*(1), 168-168. https://doi.org/10.1080/03057269908560146

Kalyon, D. Ş. (2020). The science learning environment primary school students' imagine. *Journal of Baltic Science Education, 19*(4), 605–627. https://doi.org/https://doi.org/10.33225/jbse/20.19.605

Khalaf, B. K., & Zin, Z. B. M. (2018). Traditional and inquiry-based learning pedagogy: A systematic critical review. *International Journal of Instruction, 11*(4), 545–564. https://doi.org/10.12973/iji.2018.11434a

Kola, A. J., & Kola, J. (2013). Effective teaching and learning in science education through information and communication technology [ICT] related papers. *IOSR Journal of Research & Method in Education, 2*(5), 43–47.

Laksana, D. N. L., Dasna, I. W., & Degeng, I. N. S. (2019). The effects of inquiry-based learning and learning styles on primary school students' conceptual understanding in multimedia learning environment. *Journal of Baltic Science Education, 18*(1), 51–62. https://doi.org/10.33225/jbse/19.18.51

Löfgren, R., Schoultz, J., Hultman, G., & Björklund, L. (2013). Exploratory talk in science education: Inquiry-based learning and communicative approach in primary school. *Journal of Baltic Science Education, 12*(4), 482–496. https://doi.org/10.33225/jbse/13.12.482

Massaro, B., Bellio, M., Piva, E., Schumann, S., Irato, P., & Santovito, G. (2022). What is essential is invisible to eye: A didactic research on microbiology and health education in third grade of primary school through playing and laboratory approach. *International E-Journal of Advances in Education, VIII*(22), 92–101. https://doi.org/10.51508/intcess.202223

Mulyeni, T., Jamaris, M., & Suprjyati, Y. (2019). Improving basic science process skills through inquiry-based approach in learning science for early elementary students. *Journal of Turkish Science Education, 16*(2), 187–201. https://doi.org/10.12973/tused.10274a

Narayan, J. P. (2016). Textbook embedded constructivist pedagogy for effective and Joyful learning. *International Journal of Scientific Research and Education, 4*(3), 5042–5049.

Nurpratiwiningsih, L., & Setiyoko, D. T. (2018). Development of education games map material as a learning media for elementary school students. *Journal of Primary Education, 7*(3), 249–257.

OECD. (2019). *PISA 2018 results: Combined executive summaries: Vols. I, II, III.* Retrieved from https://www.oecd.org/pisa/Combined_Executive_Summaries_PISA_2018.pdf

Pavan, C., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P., & Santovito, G. (2021). Microorganisms in the alimentation in primary school: The laboratory didactics in the teaching - learning processes of life sciences. *International E-Journal of Advances in Education, VII*(19), 48–57. https://doi.org/10.51508/intcess.202176

Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, T. (2012). Improving students' inquiry skills through reflection and self-regulation scaffolds. *Technology, Instruction, Cognition and Learning, 9*(1-2), 81-95.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Prayogi, S., Yuanita, L., & Wasis, L. (2018). Critical inquiry based learning: A model of learning to promote critical thinking among prospective teachers of physic. *Journal of Turkish Science Education, 15*(1), 43–56. https://doi.org/10.12973/tused.10220a

Puspitarini, Y. D., & Hanif, M. (2019). Using learning media to increase learning motivation in elementary school. *Anatolian Journal of Education, 4*(2), 53–60.

Rogosic, R., Heidt, B., Passariello-Jansen, J., Bjornor, S., Bonni, S., Dimech, D., . . . Dilien, H. (2021). Modular science Kit as a support platform for STEM learning in primary and secondary school. *Journal of Chemical Education, 98*(2), 439–444. https://doi.org/10.1021/acs.jchemed.0c01115

Sadi, Ö., & Cakiroglu, J. (2011). Effects of hands-on activity enriched instruction on students' achievement and attitudes towards science. *Journal of Baltic Science Education, 10*(2), 87–97.

Slavin, R. E., Lake, C., Hanley, P., & Thurston, A. (2014). Experimental evaluations of elementary science programs: A best-evidence synthesis. *Journal of Research in Science Teaching, 51*(7), 870–901. https://doi.org/10.1002/tea.21139

Song, Y., Cao, J., Yang, Y., & Looi, C.-K. (2022). Mapping primary students' mobile collaborative inquiry-based learning behaviours in science collaborative problem solving via learning analytics. *International Journal of Educational Research, 114*, 101992. https://doi.org/10.1016/j.ijer.2022.101992

Spencer, T. L., & Walker, T. M. (2011). Creating a love for science for elementary students through inquiry-based learning. *Journal of Virginia Science Education, 4*(2), 18–25.

Thaiposri, P., & Wannapiroon, P. (2015). Enhancing students' critical thinking skills through teaching and learning by inquiry-based learning activities using social network and cloud computing. *Procedia - Social and Behavioral Sciences, 174*, 2137–2144. https://doi.org/10.1016/j.sbspro.2015.02.013

Thiagarajan, S., Sammel, D. S., & Melvyn, S. I. (1974). *Instructional development for training teachers of exceptional children.* Bloomington: Indiana University.

TIMSS. (2015). *The science curriculum in primary and lower secondary grades.* Retrieved from https://timssandpirls.bc.edu/timss2015/encyclopedia/countries/hong-kong-sar/the-science-curriculum-in-primary-and-lower-secondary-grades/

Toma, R. B., & Greca, I. M. (2018). The effect of integrative STEM instruction on elementary students' attitudes toward science. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(4), 1383–1395. https://doi.org/10.29333/ejmste/83676

Unlu, Z. K., & Dokme, I. (2020). The effect of technology-supported inquiry-based learning in science education: Action research. *Journal of Education in Science, Environment and Health, 6*(2), 120–133. https://doi.org/10.21891/jeseh.632375

Watson, R. (2000). The role of practical work [w:] Good Practice in Science Teaching: What Research Has to Say, red. *M. Monk, J. Osborne, Buckingham.*

Wen, C.-T., Liu, C.-C., Chang, H.-Y., Chang, C.-J., Chang, M.-H., Chiang, S.-H. F., . . . Hwang, F.-K. (2020). Students' guided inquiry with simulation and its relation to school science achievement and scientific literacy. *Computers & Education, 149*, 103830. https://doi.org/10.1016/j.compedu.2020.103830

Widoyoko, E. P. (2016). *Evaluation of learning programs: A practical guide for educators and prospective educators* (8th ed.). Yogyakarta: Pustaka Pelajar.

Wirjawan, J. V., Pratama, D., Pratidhina, E., Wijaya, A., & Untung, B. (2020). Development of smartphone app as media to learn impulse-momentum topics for high school students. *International Journal of Instruction, 13*(3), 17-30. https://doi.org/10.29333/iji.2020.1332a

Yuliati, L., Riantoni, C., & Mufti, N. (2018). Problem solving skills on direct current electricity through inquiry-based learning with PhET simulations. *International Journal of Instruction, 11*(4), 123-138. https://doi.org/10.12973/iji.2018.1149a