JPPIPA 10(9) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Design and Construct of Magnetic Induction and Force Practicum Tools to Improve Science Process Skills

Muhammad Basir[1*], Andhy Setiawan[2], Didi Teguh Chandra[1]

[1] Physics Education Department, Universitas Pendidikan Indonesia, Bandung, Indonesia.
[2] Physics Department, Universitas Pendidikan Indonesia, Bandung, Indonesia.

Received: May 29, 2024
Revised: June 30, 2024
Accepted: September 25, 2024
Published: September 30, 2024

Corresponding Author:
Muhammad Basir
muhammadbasir20@upi.edu

DOI: 10.29303/jppipa.v10i9.7837

Abstract: The purpose of this study was to design and construct magnetic induction and force practicum tools (AlPrIGMa) to improve science process skills. This research belongs to Research and Development (R&D) research using the Hannafin & Peck development model which consists of three main stages, namely need assessment, design, as well as development and implementation. The research instruments used in this research include expert validation sheets, student response sheets, science process skills observation sheets, and science process skills test questions. The results of the assessment undertaken by 3 experts showed a percentage of tool feasibility of 89.3% with a very feasible category. In addition, the response from 10 students after testing the tools obtained an average percentage of 83% in the very good category. The results of the application of the tools showed that there was an increase in each aspect of science process skills with an average N-gain score of 0.71 in the high category. Based on the effectiveness test, the independent t result is 0.009 < alpha value (0.05), which shows that AlPrIGMa is proven effective in improving science process skills.

Keywords: Magnetic induction and force; Practicum tools; Science process skills

Introduction

One of branches of science taught at the high school level is physics, which is a branch of science that studies real and measurable natural phenomena and symptoms, both in the form of qualitative and quantitative observation results by applying mathematics as a tool (Cahyono et al., 2018). Most of physics material in high school is complex, abstract and complicated, so it is very difficult for teachers to teach all the facts, concepts, theories or formulas conventionally. Physics learning should not only be learning in the form of imparting knowledge but also a constructivist process, namely facilitating students to build their own cognition, develop skills and foster positive attitudes (Murniati et al., 2021). On the other hand, demands for curriculum achievement emphasize that ideal learning must be able to encourage overall student creativity, make students active, and achieve learning goals effectively. Apart from that, planning of learning must also optimize the active learning of students which emphasizes strengthening process skills that can be applied in everyday life.

The selection of strategies to be applied in learning must refer to two things, namely optimizing the interconnection of all learning elements and involving all of the students' senses (Cahyono et al., 2018). One of learning methods that can optimize these two things is experiment-based learning using a practicum tool that can simultaneously illustrate physical phenomena and abstract concepts (Ghoniem et al., 2018; Ridho et al., 2021). In this case it can also be supported by a scientific learning approach namely involving students to learn directly by paying attention, observing, investigating

How to Cite:
Basir, M., Setiawan, A., & Chandra, D. T. (2024). Design and Construct of Magnetic Induction and Force Practicum Tools to Improve Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6516–6524. https://doi.org/10.29303/jppipa.v10i9.7837

and analyzing phenomena in everyday life related to the material being studied. Of course, this will greatly support the achievement of increased mastery of concepts and train students' science process skills, especially in physics learning.

Science process skills (abbreviated KPS in Indonesian) are skills that need to be instilled in students, to be used in creating knowledge, solving problems and formulating results (Falloon, 2019; Fitria, 2021; Lavi et al., 2021; Persky et al., 2019). The importance of training and developing KPS in students will be very useful for them not only as a process for building knowledge in learning but also useful in everyday life, so KPS is very important for students to have because it is an exercise in logical and scientific thinking to solve an existing problem in real life. In process skills, there are three components that need to be developed, namely: 1) the ability to use the mind (intellectual skills), 2) the ability to reason, 3) efficient and effective actions to achieve certain results including creativity. The aspects that are often used to assess science process skills are observing, grouping, interpreting, predicting, asking questions, hypothesizing, planning experiments, using tools or materials, applying concepts, communicating, and experimenting (Ekici et al., 2020; Hunegnaw et al., 2023; Sutiani et al., 2021; Wijaya et al., 2021; Yildiz et al., 2021).

Practicum activities will shape students' science process skills, especially independent practicums such as project-based practicum activities that are more effective than guided practicums (Jehadan et al., 2020; Marino et al., 2020). Appropriate practicums and guidance in learning physics can facilitate students to develop their science process skills, especially in paying attention or observing, grouping, asking questions, hypothesizing, planning experiments, using tools and materials, applying concepts, carrying out experiments, concluding, and communicating (Azevedo et al., 2023; El Kharki et al., 2021; Lithoxoidou et al., 2023). However, the physics practicum process, especially at the high school level, is still rarely carried out and needs to be increased in frequency, based on National Education Research and Development Data (2015), the frequency of science practicum activities (including physics) in 8,886 public and private high schools in Indonesia is only 36% of the classroom learning activities total (Saputro et al., 2019).

One of the physics materials taught in grade 12 high school is magnetic induction and force. This material is less concrete, but its application is very often found in real life (Rettob et al., 2021). Based on the observation results and interviews with physics teachers and students at one of the schools in Bontang, it was shown that students had difficulties in understanding physics learning material, caused by learning activities that involved memorizing formulas, taking notes and working on questions rather than understanding concepts through practical activities. In this case, there needs to be a practicum, so that the learning of magnetic induction and forces is more contextual so that it encourages students to make connections between the knowledge they have and its application in their daily lives (Harahap et al., 2023).

On the other hand, the author's experience as a laboratory manager at a high school in Bontang observes that there is still a need for creativity and development in existing magnetic induction physics practicum tools, so that they can be more effective in supporting and adding to the scientific knowledge, especially in the field of magnetic induction and forces. Apart from that, most practicum tools still depend on practicum tools purchased on the market which contain combined tools or so-called integrated instrument components (abbreviated KIT in Indonesian). Even though it is not easy to obtain, the magnetic induction and force material KIT is classified as a tool that has national standards. There is also a magnetic KIT developed by Ridho et al. (2021) which shows several characteristics of the tool that can still be developed, namely the results of the suitability of the tool concept with theory reaching 68.250 from 700, the level of accuracy and precision is 0.93-0.99 (very high) and the error percentage is 1.8%-9.7% (very low). Likewise, the standard school practicum tools on the topic of magnetic induction and force used in the experimental topic of the concept of magnetic induction and force are classified as types of demonstration, application and bridge tools, which demonstrate and apply as well as bridge a physics concept so that it can be seen clearly when used, including: (1) a magnetic field around a current-carrying conductor which is capable of knowing that variable electric current can produce magnetic field symptoms, characterized by the movement of iron filings to form magnetic field lines and the deviation of the needle on the compass in straight wire, coiled wire and or solenoid experiments; (2) magnetic force or Lorentz force, which can be observed in a straight wire in a magnetic field by regulating the amount of electric current flow to produce spontaneous movement in the wire which shows that the wire has current and the magnetic field influences the occurrence of Lorentz force symptoms; (3) the application of Lorentz force, which is able to show that electric current flowing in a long wire forms a systematic coil and in a magnetic field can produce movement/rotation in an electric motor or mini generator. So that from these three experimental topics, after being observed in the experiment, the KPS aspects that have the potential to be improved further for the development of practicum tools for magnetic induction and force are predicting observation results, applying concepts, and communicating the results of experiments on magnetic induction material as well as with other types of practicum tools other than demonstration and application.

In this research, the induction and magnetic force practicum tools that was developed can be used to optimize KPS both in general and specifically on the potential that can still be improved from standard school practicum tools. Apart from showing magnetic phenomena or symptoms that occur in wires carrying electric current and magnetic forces, the tool that was developed is also equipped with a combination of automatic measuring instruments for the magnitude of magnetic fields and electric currents which can encourage students to compare quantities or variables that influence each other, improve process skills in the aspect of forecasting or using patterns from observations accurately to express what happens in situations that have not been observed, use concepts from new experiences to explain what is happening and provide a systematic picture of empirical data from experiments or observations using graphs, tables or diagram.

The types of magnetic induction and force practicum tools that was developed include two types, namely magnetic field experiment tools and magnetic force or Lorentz forces experiment tools. Magnetic field device around a current-carrying wire is classified as a model type, which is used to visualize or concretize (physical) the concept of magnetic induction, whether in a straight wire carrying a current, a coiled wire, a solenoid coil and a toroid. This can facilitate students' understanding of the concept of the factors that influence magnetic field strength and its relationship with the magnetic force shown in the solenoid coil and the need to practice the skills of observing, interpreting, planning experiments and applying the concept of magnetic fields (Fajrin et al., 2021).

Furthermore, the magnetic force or Lorentz force tools using a digital coffee powder scale is classified as a bridge type, a tool that bridges the concept to clarify the meaning of the Lorentz force concept qualitatively and quantitatively on straight wires and parallel wires in a magnetic field. The function of this tool becomes very dominant remembering that the concept of Lorentz force is still very abstract for most students. Besides, the influence of conventional learning methods without practical activities can hinder mastery of the concept, especially Lorentz force (Rettob et al., 2021). KPS that need to be improved in Lorentz force tools are forecasting, asking questions, hypothesizing, communicating and planning experiments (Cahyono et al., 2018).

Apart from that, the supporting measuring tool developed is a combination of magnetic field and electric current measuring tools using a UGN3503 hall effect sensor based on an Arduino Uno multicontroller and a dual volt ammeter assembled independently, which is a tool that is classified as a source type, namely solving problems presented in practicum tools for problems-solving that is heuristic and investigative. As in research conducted by Putri et al. (2021), measuring activities using sensors can provide precise results so that they can train process skills of interpreting, using tools and materials, and applying the Biot-Savart concept.

Research on the theoretical feasibility of practicum tools has the potential to make a significant contribution to the development of physics learning (Ardianto et al., 2023). By identifying the required eligibility criteria and evaluating existing practicum tools, it will be possible to help educational institutions make better decisions in choosing the right practicum tools. Thus, practicum tools must meet certain eligibility standards in order to provide maximum contribution to the learning process. This includes suitability to the implemented curriculum, ability to support the formation of concepts and science process skills, ability to increase motivation, reliability in terms of accuracy, as well as its ease of use and safety that relate to the attractive appearance of the practicum tools (Ramadhani, 2020). This research focused on assessing the suitability of practicum tools so that they can be used in physics learning, especially in the concepts of magnetic induction and force at the high school level.

This research is in the form of developing a practicum tools for magnetic induction and force which is intended as a learning media innovation that provides students with the opportunity to be directly and actively involved in the learning process related to magnetic induction material both qualitatively and quantitatively. This can certainly provide a different and interesting experience in the physics learning process for students. The contribution of this research is to increase the scientific knowledge in physics learning and provide an alternative physics practicum tool that is easy to obtain and suitable for use as a support in learning activities that can improve students' science process skills in schools, especially those where magnetic induction and force practical practicum tools are still very limited. Therefore, in the future physics learning is expected to be more dynamic and meaningful for students and able to build students' cognitive and psychomotor competencies collectively and contextually.

Method

This research is development research. It is intended to produce a certain product and test the feasibility of the resulting product (Herawati et al., 2023). The development model used in this research is the Hannafin & Peck model which consists of 3 main stages, namely needs assessment, design, as well as development and implementation. This model has the advantage of a systematic working procedure that is product-oriented. Each step always refers to the previous step that has been improved, so that an effective product is obtained (Rohmansyah et al., 2020). At the needs assessment stage, researchers carried out curriculum analysis, namely using the Kurikulum Merdeka, analysis of magnetic induction and force materials, analysis of science process skills based on their aspects, analysis of use and safety, and analysis of feasibility criteria for practicum equipment. The design stage or product design was made based on a needs assessment all in the design of the tool circuit, the design of the measuring instrument, and the design of the test wire used. The stage of development and implementation was the stage of making tools based on the design that had been created. At the same time at this stage a feasibility assessment was carried out by experts and a limited trial was carried out by students.

The practical equipment for induction and magnetic force (AlPrIGMa) that was designed and developed was tested for feasibility by experts until it was declared feasible. Then, the practicum tools that were feasible were tested on a limited basis with students. After the product has been feasible and tested, the research continued by applying the tool to learning, namely using an experimental research type where the researcher grouped respondents into two groups, namely the experimental group and the control group, to see the differences in the increase in students' science process skills after using AlPrIGMa and its effectiveness. The research instrument used was a non-test instrument consisting of a validation sheet for the suitability of the tool which was assessed by three experts, a student response sheet which was filled in by 10 students after testing the tool, and a science process skills observation sheet to assess student activities when applying tools in learning. Meanwhile, the test instrument was 22 multiple choice questions on science process skills. Aspects of feasibility assessment by experts consist of the suitability of the tool with the curriculum, the ability of the tool to build concepts and science process skills, accuracy and stability of measurements, ease of use and safety, attractiveness of the tool, as well as the accuracy of the supporting materials used. Then, aspects of student response were ease of operation, understanding of the concept, measurement stability, tool attractiveness, and tool safety. Meanwhile, indicators of science process skills assessed through tests and observations were observing, grouping, interpreting, predicting, asking questions, hypothesizing, planning experiments, applying concepts and communicating (Purba et al., 2021). The data analysis technique used in assessing the feasibility of practicum tools was a weighted score which was interpreted using a percentage formula and categorized from a range of 75-100%, namely (very good/highly feasible), 50-74.99% (good/feasible), 25–49.99% (less/barely feasible), 0–24.99% (very poor/not feasible) adapted from (Jehadan et al. (2020). Meanwhile, data analysis techniques for evaluating the improvement of science process skills used N-gain scores from pretest and posttest scores with the criteria N-gain > 0.7 (high), 0.3 < N-gain < 0.7 (medium) and N-gain < 0.3 (low) and a hypothesis test was carried out which met the requirements for assessing the effectiveness of AlPrIGMa using SPSS with α = 0.05, if the sig. > 0.05 means there is no significant difference or AlPrIGMa is not effective, whereas if the value is sig. < 0.05 then there is a significant difference or AlPrIGMa is effective (Zulmi et al., 2020).

Result and Discussion

In general, the AlPrIGMa practicum tools consists of two experiments, namely the magnetic induction practicum tools and the magnetic force or Lorentz force practicum tools. Based on the results of trials carried out independently by experts and students. The following is a display of a series of magnetic induction and force experiment tool that has been designed and arranged.

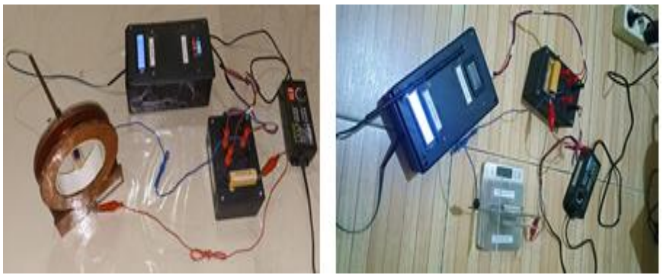

Figure 1. Series of experiments on induction and magnetic force

Figure 2. Series of circular wire, straight wire, solenoid and toroid

This magnetic induction experiment was made from basic tools and materials consisting of a magnetic field and electric current strength measuring instrument (Avomagmeter), 0.8 mm enamel wire which was formed and attached to a plywood and acrylic support by varying the shape, size and number of coils and circle radius. In a circular wire, the number of turns starts from 90 turns, 105 turns, 120 turns, 135 turns, 150 turns and the radius of the circle varies from 3 cm, 4 cm, 4.5 cm, 5.5 cm and 7 cm. Meanwhile, on a solenoid wire, the magnetic field size is calculated based on changes in the electric current variable and the number of turns starting from 140, 120 and 100 turns, but the length of the wire and the radius of the wire winding remain 140 cm, 1.5 cm. For toroids, determining the difference in magnetic field magnitude can be done by changing the electric current, varying the winding variables and diameter, namely 65 turns, radius 1.25 cm, 75 turns with radii 1.25 cm, 1.5 cm, and 2 cm and 85 turns with a radius of 1.25 cm. Meanwhile, the magnetic force experiment (Lorentz force) uses tools and materials consisting of Lorentz force measuring instruments using digital scales and avomagmeters and using variations of straight wire with lengths of 10 cm, 20 cm and 30 cm. The natural magnetic field uses 2 neodymium magnets measuring 50 x 15 x 5 mm.

In the magnetic induction and force experiment, there are several experimental tools and materials that have been prepared and tested directly to see the level of accuracy from the results of calculating the percentage error of the tools made compared to measurements using existing measuring tools or calculated using the calculation formulas in physics concept. The followings are the results of calculations from trials that have been carried out either independently or by experts and students.

Table 1. Tool Test Results

Tool Types	Average Test Results	Average Ideal Results	Percentage error	Percentage Accuracy	Correction
Conductor Wire	0.292 Ω	0.290 Ω	1.30 %	98.7%	0.290 ± 0.003
Magnetometer	0.0588 T	0.0595 T	1.08 %	98.9%	0.059 ± 0.0007
Dual Volt Ammeter	1.1002 A	1.017 A	2.33 %	97.7%	1.10 ± 0.017
	8.597 V	8.573 V	0.15 %	99.9%	8.60 ± 0.025
Digital Scales	0.0112 N	0.0113 N	2.23 %	97.8%	0.011 ± 0.0002
Total Average			1.17 %	98.8%	

Overall, the results of testing the tools made compared to existing tools showed that the average error rate reached an average of 1.17% or the accuracy percentage was 98.8%. It means that overall, several types of tools and materials that were used and made into the practicum tools are classified as having minimal errors or the accuracy of the measurements can still be trusted. Apart from that, it is also known that each result of the error propagation of the tool after testing is as shown in the table. Its function is as a measuring limit that can still be tolerated when using materials or obtaining measuring results from the tool. After testing the accuracy level of each tool and material, the feasibility of AlPrIGMa was then assessed based on validation by three lecturers. Each of them adapts to the existing eligibility criteria as in the following assessment results table. The feasibility assessment was carried out before the practicum tools were applied in classical classroom learning so that when the practicum tools were used, they met the standards. Based on feedback from expert lecturers, improvements were then made to perfect the practicum tools in accordance with suggestions for improvement. The following are the results of expert assessments of the AlPrIGMa practicum tools that have been created and tested.

Table 2. Expert Feasibility Assessment

Indicators	Percentage of Expert Assessment (%)	Category
Conformity to the Curriculum	91.7	Highly Feasible
Build science process concepts and skills	89.1	Highly Feasible
Accuracy and stability of measurements	88.9	Highly Feasible
Ease of use	89.2	Highly Feasible
Security	87.5	Highly Feasible
Accuracy of Supporting Materials	95.2	Highly Feasible
Average	90.3	Highly Feasible

Overall, the tool tested received a very decent assessment from experts with an average total score for all indicators of 90.3%. Based on the results of this evaluation, it can be concluded that the tool tested has very good compatibility with the curriculum, is effective in helping build science process concepts and skills, is easy to use, and is safe for use in learning and has stability and accuracy in measurements. The supporting materials used were also already appropriate. This makes this tool a viable choice to support magnetic induction and force practicum activities. After the improvement and assessment of the practicum tools by experts was completed, a limited trial was carried out which was attended by 10 students representing the users to see their response to using the tools, as well as their ability to understand the physics concepts being taught, including feedback regarding their experience using the practicum tools, difficulties they faced, and suggestions for improvement. The following are the results of students' responses after testing the magnetic induction and force practicum tools.

The assessment given by students shows that all indicators received a "Very Good" rating with an average score of 84.5%. This shows that based on evaluations from students, these aspects have been fulfilled well in the research conducted. Likewise, with the improvement and effectiveness of AlPrIGMa practicum tools based on students' science process skills obtained from the results of the pretest and posttest which have been carried out statistical tests and hypothesis tests, the following are the results.

Table 3. Student Responses

Indicators	Percentage of Student Responses (%)	Category
Ease of operation	76.7	Very Good
Concept understanding	77.5	Very Good
Measurement stability	90.0	Very Good
Tool attractiveness	93.3	Very Good
Tool security	85.0	Very Good
Average	84.5	Very Good

Table 4. Increase in Science Process Skills and Their Effectiveness

Group	Pretest	Posttest	<g>	Independent t-Test	KPS Performance Assessment
Experiment	54.0	86.0	0.71	0.009	85
Control	52.7	82.9	0.65		76

Based on the results of the research above, the increase in the experimental group or group that was treated using AlPrIGMa, from the pretest and posttest scores obtained an average N-gain score of 0.71 in the "high" category. This shows that the treatment given after learning using AlPrIGMa experienced a high increase in science process skills. To determine the improvement in each aspect, namely KPS 1 (observing), KPS 2 (classifying), KPS 3 (interpreting), KPS 4 (predicting), KPS 5 (asking questions), KPS 6 (hypothesizing), KPS 7 (planning experiments), KPS 8 (applying concepts), KPS 9 (communicating), the following graph is presented.

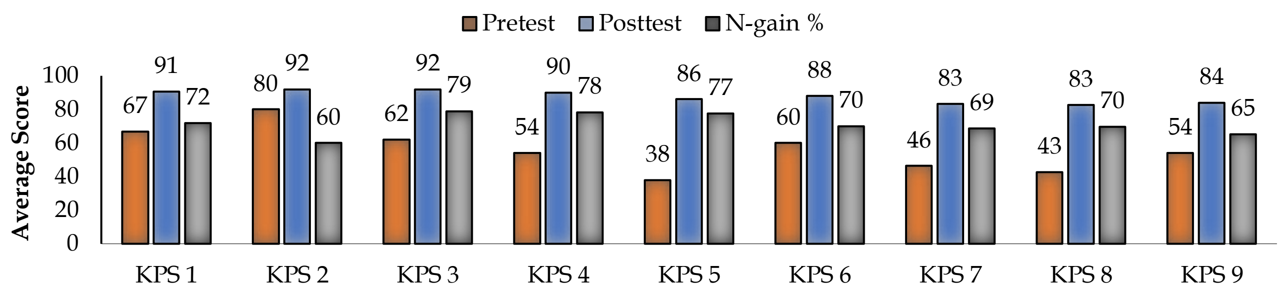

Figure 3. Increase in KPS for each indicator

Based on the graph above, from the improvement values, it is known that the highest scores sequentially are in the aspects of interpreting, predicting, asking and observing which are at the high improvement category level from 0.72 to 0.79 compared to other aspects which are in the medium category range from numbers 0.65 to 0.70, namely hypothesizing, applying concepts, planning experiments, communicating. Meanwhile, the lowest N-gain score is in the classifying aspect with a score of 0.60 but is still in the medium category. These things happen because of differences in each student's ability to answer questions and construct concepts into process skills. The results of the observational assessment of the performance of science process skills show that the average value of indicators is different between the experimental group and the control group. It can be seen that the average value of the experimental group was 85% while the control one was 75.6%. From this assessment, it can be concluded that the experimental group tends to have better performance in almost all indicators of science process skills compared to the control group.

Furthermore, to determine the effectiveness of AlPrIGMa from the difference in scores between the experimental group and the control group, it was necessary to carry out statistical tests. Based on the normality and homogeneity tests carried out, it can be seen that the data obtained meets the requirements for an independent t test because the data is normal and homogeneous. So it can be seen that the results of the t test show that there is a significant difference between the experimental group and the control group with the number 0.009 < alpha value (0.05), in other words the AlPrIGMa practicum tools is very effective for improving science process skills.

Research on the design of magnetic induction and force practicum tools (AlPrIGMa) has several opportunities and challenges for researchers in the future. Firstly, AlPrIGMa, which is already feasible, can still carry out further development, namely by increasing the experimental variables for each material content, or adding experiments on tools for applying induction and Lorentz forces that are relevant to everyday life, either in the form of demonstration experiments or quantitative experiments. Second, it is important to continue evaluating the effectiveness of using AlPrIGMa in improving students' science process skills. This evaluation can help identifying aspects that have not been observed or need improvement so as to ensure that the use of this practicum tools has a more positive and sustainable impact on learning. Thirdly, AlPrIGMa can also be tried in a project-based or problem-based learning, for example to improve students' creative and critical thinking abilities (Widiarini et al., 2022). Fourth, further research that can be carried out in the development of AlPrIGMa is by integrating it with contemporary technology such as the use of programs and other sensors connected to software or IOT (Internet of Things) based simulations so that experimental data can be obtained automatically (Wahyudi et al., 2023).

Conclusion

The results of the research show that the magnetic induction and force practicum tools called AlPrIGMa has been successfully developed and is suitable for use in the learning process. It can be seen that the tool is considered very suitable by experts and very good for use by students with average percentages of 90.3% and 84.5% respectively. The use of AlPrIGMa in learning has provided a significant increase in every aspect of science process skills where the average N-gain reaches the high category of 0.71. The aspects are observing, classifying, interpreting, predicting, asking questions, hypothesizing, planning experiments, applying concept, communicating. And also AlPrIGMa has been proven to be effective for use improving science process skills on magnetic induction and forces material as seen from the independent t test value of 0.009. By using specially designed practicum tools such as AlPrIGMa, it is expected that it has a positive impact in improving the quality of learning in the classroom. Students can become more involved in hands-on experiments, which can increase their interest and motivation in studying science. Schools and educational institutions may consider investing in AlPrIGMa or similar practicum tools to enrich students' learning experiences. This will help create a more dynamic and interactive learning environment. Teachers who will use AlPrIGMa in teaching magnetic induction and forces should first have sufficient information on the specifications and instructions as well as standards for use in order to optimize all components of the tool properly and correctly.

Acknowledgments
The author would like to thank the supervisor and expert lecturers who have provided guidance, assistance, support, and encouragement. Thank you to the teachers of SMA IT DHBS, especially Mrs. Meilani who helped in this research and to all students of class XII IPA SMA IT DHBS Bontang.

Author Contributions
Conceptualization, Muhammad Basir and Andhy Setiawan; methodology, Muhammad Basir and Didi Teguh Chandra; software, Muhammad Basir; validation, Muhammad Basir, Andhy Setiawan and Didi Teguh Chandra; formal analysis, Muhammad Basir; investigation, Muhammad Basir; resources, Muhammad Basir. ; data curation, Muhammad Basir; writing-preparation of initial draft, Muhammad Basir; writing-review and editing, Muhammad Basir; visualization, Muhammad Basir; supervision, Muhammad Basir and Andhy Setiawan; project administration, Muhammad Basir; acquisition of funds, Muhammad Basir. All authors have read and approved the published version of the manuscript."

Funding
This research was funded independently by the author.

Conflicts of Interest
The authors declare no conflicts of interest. No one other than the authors had a role in the design of the study; in the collection, analysis, interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

References

Ardianto, A., Suseno, N., Rosa, F. O., & Prihandono, E. (2023). Pengembangan Alat Praktikum Fisika Pada Topik Hukum Kekekalan Momentum Berbasis Arduino Uno Menggunakan Sensor Ultrasonik Hc-Sr94. *Jurnal Firnas*, *4*(1), 36–42. https://doi.org/10.24127/firnas.v4i2.4425

Azevedo, E., Ramos, A., Valério, C., Araújo, R., & Mesquita, I. (2023). Diving into Real-World Practicum in Physical Education: Deconstructing and Re-Signifying Pre-Service Teachers' Reflections. *Education Sciences*, *14*(1), 11. https://doi.org/10.3390/educsci14010011

Cahyono, A., & Admoko, S. (2018). Pengembangan Alat Praktikum Gaya Lorentz Sebagai Media Pembelajaran Fisika. *Jurnal Pendidikan Fisika*, *7*(2), 180–184. https://doi.org/10.26740/ipf.v7n2.p%25p

Ekici, M., & Erdem, M. (2020). Developing Science Process Skills through Mobile Scientific Inquiry. *Thinking Skills and Creativity*, *36*, 100658. https://doi.org/10.1016/j.tsc.2020.100658

El Kharki, K., Berrada, K., & Burgos, D. (2021). Design and Implementation of a Virtual Laboratory for Physics Subjects in Moroccan Universities. *Sustainability*, *13*(7), 3711. https://doi.org/10.3390/su13073711

Fajrin, V. P., Ruhiyat, Y., & Darman, D. R. (2021). Pengembangan Alat Peraga Fisika Crane Magnetic Pokok Bahasan Medan Magnet Pada Selenoida. *Jurnal Luminous: Riset Ilmiah Pendidikan Fisika*, *2*(1), 1. https://doi.org/10.31851/luminous.v2i1.5134

Falloon, G. (2019). Using simulations to teach young students science concepts: An Experiential Learning theoretical analysis. *Computers & Education*, *135*, 138–159. https://doi.org/10.1016/j.compedu.2019.03.001

Fitria, D. (2021). Hubungan Keterampilan Proses Sains Dan Kemampuan Berpikir Kritis Padamateri Suhu Dan Kalor. *Journal Evaluation in Education (JEE)*, *1*(3), 83–90. https://doi.org/10.37251/jee.v1i3.137

Ghoniem, R. M., Abas, H. A., & Bdair, H. A. (2018). Three-dimensional Simulation System based Intelligent Object-oriented Paradigm for Conducting Physics Experiments. *Procedia Computer Science*, *135*, 490–502. https://doi.org/10.1016/j.procs.2018.08.201

Harahap, N. R., Ompusunggu, E., Marpaung, N., & Pulungan, S. E. (2023). Penerapan Model Project Based Learning (PjBL) Terhadap Kreativitas Siswa Pada Materi Kemagnetan. *Jurnal Inovasi Pembelajaran Fisika*, *8*(2), 77–82. https://doi.org/10.24114/inpafi.v8i2.18686

Herawati, Setiawan, A., & Hidayat, A. (2023). Development of Physics LMS Based on Science Literacy Related Energy Content in Agricultural Context (Farmer). *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4523–4529. https://doi.org/10.29303/jppipa.v9i6.3590

Hunegnaw, T., & Melesse, S. (2023). An evaluative study of the experimental tasks of the Ethiopian grade 12 chemistry textbook considering developing "science process skills." *Cogent Education*, *10*(1). https://doi.org/10.1080/2331186X.2023.2208944

Jehadan, H., Nur, M., & Supardi, Z. A. I. (2020). The Development of Physics Guided Inquiry Learning Package To Facilitate The Science Process Skills of Senior High School. *International Journal for Educational and Vocational Studies*, *2*(10), 847–852. https://doi.org/10.29103/ijevs.v2i10.3307

Lavi, R., Tal, M., & Dori, Y. J. (2021). Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning. *Studies in Educational Evaluation*, *70*, 101002. https://doi.org/10.1016/j.stueduc.2021.101002

Lithoxoidou, A., & Georgiadou, T. (2023). Critical Thinking in Teacher Education: Course Design and Teaching Practicum. *Education Sciences*, *13*(8), 837. https://doi.org/10.3390/educsci13080837

Marino, M. P., & Crocco, M. S. (2020). The pre-service practicum experience and inquiry-oriented pedagogy: Evidence from student teachers' lesson planning. *The Journal of Social Studies Research*, *44*(1), 151–167. https://doi.org/10.1016/j.jssr.2019.02.001

Murniati, M., Desti, M. A., & Sriyanti, I. (2021). Analisis Keterampilan Proses Sains (Kps) Mahasiswa Calon Guru Fisika Di Fkip Universitas Sriwijaya. *Jurnal Inovasi Dan Pembelajaran Fisika*, *8*(2), 208–217. https://doi.org/10.36706/jipf.v8i2.15295

Persky, A. M., Medina, M. S., & Castleberry, A. N. (2019). Developing Critical Thinking Skills in Pharmacy Students. *American Journal of Pharmaceutical Education*, *83*(2), 7033. https://doi.org/10.5688/ajpe7033

Purba, D., Lubis, R., & Zulfadli. (2021). George Polya's Thought on Problem Solving. *Journal of MathEdu Mathematic Education Journal*, *4*(1), 25–31. Retrieved from http://journal.ipts.ac.id/index.php/MathEdu

Putri, A., & Saehana, S. (2021). Pengembangan Alat Praktikum Menggunakan Sensor Ultrasonik Dikombinasikan Dengan Arduino Sebagai Media Bantu Praktikum Materi Gelombang. *Jurnal Inovasi Dan Pembelajaran Fisika*, *8*(1), 1–13. https://doi.org/10.36706/jipf.v8i1.12710

Ramadhani, S. P. (2020). *Pengelolaan Labolatorium*. Depok: Yayasan Yiesa Rich.

Rettob, R. J., Poluakan, C., Tulandi, D. A., Mongan, S. W., & Polii, J. (2021). Students learning difficulties in understanding the Lorentz force. *Journal of Physics: Conference Series*, *1968*(1), 012041. https://doi.org/10.1088/1742-6596/1968/1/012041

Ridho, M., Rahmad, M., & Wulandari, S. (2021). Constructivism-Based Magnetic KIT Design as a

Science Learning Media. *Journal of Physics: Conference Series*, *2049*(1), 012042. https://doi.org/10.1088/1742-6596/2049/1/012042

Rohmansyah, I., & Kholiq, A. (2020). Pengembangan KIT Optik Berbasis Sensor Infrared Untuk Peserta Didik SMA. *IPF: Inovasi Pendidikan Fisika*, *9*(3), 473–478. https://doi.org/10.26740/ipf.v9n3.p473-478

Saputro, V. C. E., Prabowo, P., & Admoko, S. (2019). Pengembangan Alat Peraga Mesin Carnot Sebagai Media Pembelajaran Dengan Model Pembelajaran Inkuiri Terbimbing. *Jurnal Inovasi Pendidikan Fisika*, *08*(02), 716–721. https://doi.org/10.26740/ipf.v8n2.p%25p

Sutiani, A., Situmorang, M., & Silalahi, A. (2021). Implementation of an Inquiry Learning Model with Science Literacy to Improve Student Critical Thinking Skills. *International Journal of Instruction*, *14*(2), 117–138. https://doi.org/10.29333/iji.2021.1428a

Wahyudi, W., Yahya, M. D., Jenuri, J., Susilo, C. B., Suwarma, D. M., & Veza, O. (2023). Hubungan Penggunaan Multimedia dalam Pembelajaran terhadap Peningkatan Hasil Belajar Peserta Didik. *Journal on Education*, *6*(1), 25–34. https://doi.org/10.31004/joe.v6i1.2910

Widiarini, P., Rapi, N. K., Pramadi, I. P. W. Y., & Udayana, K. W. (2022). Development of Project-Based Electronics Practicum Module with Virtual Lab to Increase Students' Creativity. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1135–1141. https://doi.org/10.29303/jppipa.v8i3.1364

Wijaya, I. K., Artini, N. P., Kristiandayanti, N. K., Hignasari, L. V., Indrawan, I., & Sinta Diarini, I. G. A. (2021). The Strategy of Science Process Skills Development in Chemistry Learning of Junior High School Level in The Era of Covid-19 Pandemic. *Proceedings of The 6th Asia-Pacific Education And Science Conference, AECon 2020, 19-20 December 2020, Purwokerto, Indonesia*. https://doi.org/10.4108/eai.19-12-2020.2309121

Yildiz, C., & Guler Yildiz, T. (2021). Exploring the relationship between creative thinking and scientific process skills of preschool children. *Thinking Skills and Creativity*, *39*, 100795. https://doi.org/10.1016/j.tsc.2021.100795

Zulmi, F. A., & Akhlis, I. (2020). Pengembangan LKPD berekstensi EPUB berbasis Discovery Learning untuk Mengembangkan Keterampilan Berpikir Kritis Peserta Didik. *Unnes Physics Education Journal*, *9*(2), 209–216. Retrieved from http://journal.unnes.ac.id/sju/index.php/upej