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THE BEST LABORATORY WORK TYPE TO IMPROVE HIGHER ORDER THINKING SKILLS AND SCIENTIFIC ATTITUDE

[1]Adi Pramuda, [1]Lia Angraeni, [1]Soka Hadiati, [2]Mislan Sasono
[1] Physics Education, IKIP PGRI Pontianak, Indonesia
[2]Department of Physics, Faculty of Education, Universitas PGRI Madiun, Indonesia

email: adipramuda@ikippgriptk.ac.id, lia060787@gmail.com, sokahadiati@ikippgriptk.ac.id, mislan@unipma.ac.id

ABSTRACT

This study aims to determine the effectiveness of the comprehensive laboratory work (lab work) type which is the combinations of deductive, problem solving, and technical skills type in increasing the higher-order thinking skills (HOTS) and scientific attitudes as well as empirical testing the compatibility of this comprehensive type against higher HOTS and scientific attitudes. The study involved 100 students' level two physics majors consisting of 4 randomly selected classes with cluster random sampling techniques. Scientific attitudes are measured by the scale of attitudes including indicators of curiosity, critical attitudes, and cooperation. HOTS are measured by tests that include analytical, evaluation and creating skills. This study is experimental research with the randomized Solomon four-group design. The effectiveness test of the comprehensive laboratory type in this study using the Nonparametric Kruskal Wallis test. Model match analysis is performed with the structural equation model (SEM). The results showed that there were significant differences in HOTS and scientific attitude score after the application of the comprehensive lab work type. The average student score taught with the comprehensive laboratory type is higher than that of students taught with the deductive type.

Keywords: Higher-order thinking skills, laboratory work, scientific attitude.

Abstrak

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Introduction

The 4.0 industrial revolution era has led colleges to implement holistic learning through social, spiritual, technological, cultural and environmental preservation. This era demanding learners to have comprehensive capabilities including mastery of technical skills, caring and responsibility, productive life skills, higher-order thinking skills (HOTS), character, mutual attitude respect, scientific attitude (Gleason, 2018). Learning science with technology integration will improve students' science achievement (Yaki et al, 2019; Kaushal & Panda, 2019). Therefore, learning in college is geared toward technology that is oriented towards the needs of the community and career.

Globalization and technological advances add the urgency to the need for HOTS to solve problems in everyday life as a prerequisite for success in the 21st Century (Saavedra & Opfer, 2012). HOTS are needed to effectively solve problems, communicate and collaborate with others, and understand creative ideas (Kosturko, McQuiggan & Sabourin 2015:85). Learning that considers the involvement of HOTS will be able to lead students to think logically by using reasoning and associate the knowledge that is possessed to resolve the problem. HOTS as one of the key successes plays a role in making the right and logical decisions, and solving problems in everyday life need to be special attention.

Students ' thinking skills should also be supported with a good attitude. The attitude which is shown by each individual reflects the feeling. McHugh & Way (2018:2), concluded that the attitude shown as a person's response to his environment. Balta, Mason, & Singh (2016), concluded that attitudes can affect success in solving problems. University as an institution has a function of transferring knowledge and educating the values. Rubini & Liliasari (2013) concluded that scientific attitudes are important to develop and educate during lectures because they tended towards the positive development of values in student life, automatically embed the positive values reflected in the actions of students.

The PISA data reported by the Organization for Economic Co-Operation and Development (OECD) in 2015 showed that Indonesia had a 62 ranking of 70 countries. It shows low HOTS of high school students in Indonesia. Husamah, Fatmawati, & Setyawan (2018) shows HOTS students in Malang are in low category i.e. respectively 59%, 58%, and 57% for self-thinking, critical thinking, and creative thinking. Ahmad, Prahmana, Kenedi, Helsa, Arianil, & Zainil (2017) shows 60% of students in Padang have HOTS on low category. Rubini & Liliasari (2013) shows the scientific attitude of students in Indonesia in the first semester is categorized as low so that the development of lecture models is needed. Pannerselvam & Muthamizhselvan (2015) traced the scientific attitude of students in India who attended the state school in low categorized. Pitafi & Farooq (2012) showed a lack of scientific attitude in Pakistan students after learning. Many studies show that HOTS and the scientific attitudes of learners are still low and need to be improved in learning. Learning should be designed with a variety of innovative models, methods, and media.

Activities in learning physics require direct contact with objects that want to be explored through experiments in lab work. The experience gained through experiment will be more meaningful for learners. This is related to the structure of Edgar Dale's cone of experience, stating that knowledge will be easily gained with direct experience as well as a simulation or model of real experience. Lab work refers to scientific approaches including observing, asking, exploring, associating, and communicating that lead learner to acquire physical knowledge of an object by working on the task and activate the entire sensing.

The lab work is a part of teaching science that involves HOTS and scientific attitudes. Voronchenko, Klimenko & Kostina (2015), found that project-based learning with experiments in laboratories resulted in not only professional competence, however also tolerant culture that demands cooperation strategies, respecting disagreements, and can encourage students to understand differences in social phenomena. Palic & Pirasa (2012), showing that through laboratory activities then students will have a positive attitude, creative thinking and critical thinking in experiments to get the scientific results and understand the scientific principles. Valeriu (2015) stated that the attitude formed through science learning determines the success of one's individual. The science learning process will practice thinking skills in utilizing productive knowledge, such as critical thinking, efficiently problems-solving, communicating and collaborating effectively, and understanding creative ideas (Kosturko, McQuiggan & Sabourin 2015:85). The development of the HOTS-based curriculum can foster reasoning and deep understanding of Learners (Zohar

& Alboher Agmon, 2018). Madhuri, Kantamreddi, & Goteti, (2012), has designed the learning to be able to improve HOTS by developing lab work-based research. According to the study that has been described shows that science learning through lab work enhances scientific attitudes and creative thinking skills, critical thinking, and problem-solving that can be grouped into HOTS.

The lab work consists of several types with characteristics and different objectives. Chiappetta & Koballa (2010:218), classifying lab work in five types among others: (1) Science process skills, (2) deductive or verification, (3) inductive, (4) technical skills, and (5) Problem-solving. The types of lab work have a distinctive characteristic of the syntax or learning step so that the selection of the right lab work type is able to help the students achieve the competencies expected. Generally, the lab work that is often done is more likely to follow the deductive lab work type which is a laboratory activity designed to prove the theories that have been learned before. The deductive lab work type has a weakness as it spends more time on learners to determine the correct outcome rather than thinking, planning and organizing experiments (Andersson & Enghag, 2017). This indicates that the deductive lab work type has not been optimal in improving learners' performance so that it needs to be developed innovative lab work by combining the deductive, problem solving, and technical skills lab work type that becomes a comprehensive lab work that is very promising to accommodate the achievement of HOTS and scientific attitudes. The problem-solving lab work type has the ability to improve the skills to experiment and collaborate in groups (Baharom, Khoiry, Hamid, Mutalib, & Hamzah, 2015). The technical skills lab work type has an advantage in supporting the success of laboratory activities and obtaining accurate data (Chiappetta & Koballa, 2010:206). This study will test the effectiveness of the comprehensive lab work type (the combinations of deductive, problem solving, technical skills lab work type) in enhancing HOTS and scientific attitudes, as well as empirically testing the compatibility of this comprehensive type against HOTS and scientific attitude.

Methods

The study involved 100 undergraduate students in level two of physics majors in West Kalimantan Indonesia consisting of 4 randomly selected classes with cluster random sampling techniques. The comprehensive lab work type was applied to the experimental class for five learning meetings. The syntax consists of: a theoretical study, technical formulation, modeling of experiments, problems description, analysis of causes, repair and revision, evaluation, and conclusion. In the control class that uses deductive laboratory work, five learning meetings are also applied. The syntax of deductive laboratory work includes study theory, experimentation, data analysis, conclusions. The control and experiment classes are given scientific attitudes and HOTS instruments. Scientific attitude is measured by an attitude scale consisting of 20 items, with indicators such as curiosity, critical attitude, and cooperation. The HOTS was measured by a test of 12 questions. HOTS indicators in this study are problem-solving skills which include the ability to analyze, evaluate, and create. This study is experimental research with the randomized Solomon four-group design as in Table 2.

Table 2. Research Design

		Time 1 (t_1)	Time 2 (t_2)	Time 1 (t_3)
		Measure	Treatment	Measure
Random	Group A (Experiment Group 1)	M_{At1}	Tx	M_{At3}
	Group B (Control Group 1)	M_{Bt1}	-	M_{Bt3}
	Group C (Experiment Group 2)	-	Tx	M_{Ct3}
	Group D (Control Group 2)	-	-	M_{Dt3}

Table 2 shows the graphical notation of the design of four groups of Solomon. The research plan involves four classes, consisting of two experimental classes and two control classes. Two measurements were performed before treatment (at the time of t_1), one for the first experimental group and one for the first control group (M_{At1}& M_{Bt1}). The treatment (T_x) is administered (at t_2 time) to the two experimental groups (A and C). This design is chosen so that the researcher can suppress the smallest possible sources of error due to four different groups with six measurement formats (two measurements at the beginning and four measurements at the end), so that the effects can be distinguished from the interaction of testing and treatment (Levy & Ellis, 2011:155). Normality test as a prerequisite analysis in this study using the Kolmogorov–Smirnov test with Lilliefors significance corrections. The homogenization of samples is tested using Levene's test method. Test the effectiveness of the comprehensive lab work type in this study using the Nonparametric Kruskal Wallis test. The model fit analysis was done with the Structural Equation Model (SEM) using the AMOS 20 program. The model is said to meet the match criteria if the output from the program generates a fit model. The model is said to be good if the model fits with the criteria according to Kocakaya & Kocakaya (2014) as in Table 3.

Table 3. The Criteria of Fit Model

Criteria	χ2	NCP	RMSEA	GFI	AGFI	PGFI	CFI
Value	p > 0.05	<<<	< 0,08	>0,9	>0,9	>0,9	>0,9

Table 3 shows the model match criteria that must be met. The main criteria for model matches are RMSEA and χ2. If the criteria on Table 3 have been fulfilled then it can be said that the model developed has been empirically tested to improve HOTS and scientific attitude.

FINDINGS

The stages of learning a comprehensive model are developed referring to the model based on reasoning from Dounas-Frazer et al (2015). Details of the activities carried out are presented in Figure 1. Figure 1 shows the syntax of the comprehensive model and the steps of reasoning that arise during learning. This model has comprehensive steps that can develop HOTS and scientific attitude. The steps in the model consist of presenting theoretical guidance, technical formulations, experiments, problem descriptions, finding causes, repairing and revising, evaluating, and concluding. Arduino and sensors are used as measurement devices to bring up reasoning. Students' reasoning can be seen from the repair and revision activities.

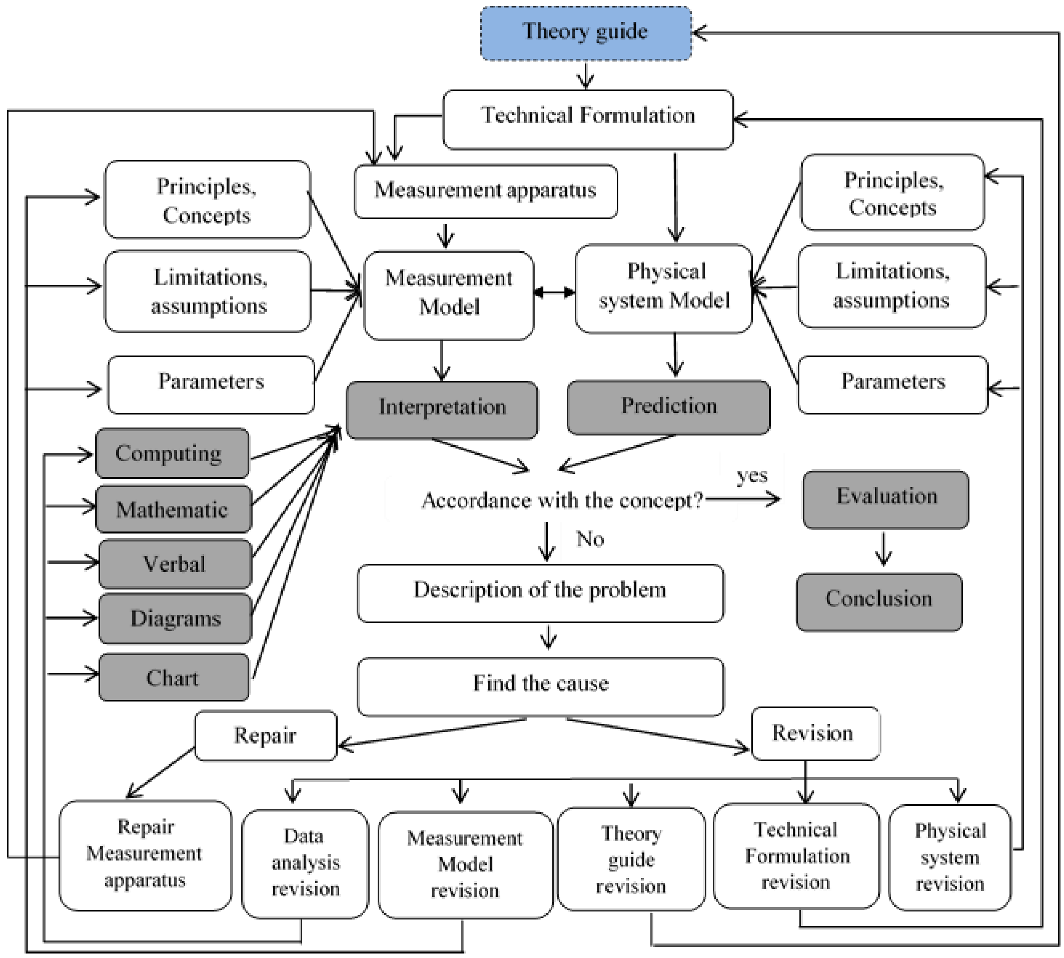

Figure 1. Syntax of comprehensive lab work

The effect of comprehensive lab work type on the enhancement of HOTS and scientific attitudes is determined by significant differences test. The normality and homogeneity test was done as a prerequisite test. Table 4 provides a summary of the test results of normality with Kolmogorov-Smirnov and homogeneity of data with Levene's test.

Table 4 shows that in HOTS data and scientific attitude has *sig value* <0.05. This shows that there are not normal and not homogeneous, further a nonparametric test is carried out with the Kruskal-Wallis test. A summary of the different test results using the Kruskal-Wallis test is presented in Table 5.

Table 5 shows that sig < 0.05, there are significant differences in HOTS and scientific attitude between experiment and control group, and the initial test against the final test experiment group. There was no significant difference in HOTS and scientific attitude between the final test against the initial test of the control group. The results of this hypothesis test show that the comprehensive lab work type developed has fulfilled the ideal criteria of Solomon's design so that it can be said to be effective for enhancing HOTS and scientific attitudes of students.

Table 4. Normality Test and Homogeneity Test Data Results

Variable	Data	Group	Kolmogorov-Smirnov			Levene's Test			
			Statistic	df	Sig.	F	df1	df2	Sig.
HOTS	Posttest	Experiment 1	.13	25	.20	6.54	1	48	.01
		Control 1	.19	25	.01				
	Pretest	Experiment 2	.17	25	.04	.55	1	48	.46
		Control 2	.15	25	.12				
	Posttest	Experiment 2	.20	25	.00	1.91	1	48	.17
		Control 2	.18	25	.02				
Scientific attitude	Postest	Experiment 1	.10	25	.20	.22	1	48	.63
		Control 1	.12	25	.20				
	Pretest	Experiment 2	.13	25	.20	.07	1	48	.78
		Control 2	.14	25	.19				
	Posttest	Experiment 2	.27	25	.00	7.20	1	48	.01
		Control 2	.14	25	.16				

Table 5. Kruskal Wallis Test Results

Dependent Variable	Sig		Decision
	HOTS	Scientific attitude	
M_{At3} vs M_{Bt3}	0.00	0.00	difference
M_{At1} vs M_{At3}	0.04	0.00	difference
M_{Ct3} vs M_{Dt3}	0.00	0.00	difference
M_{Ct3} vs M_{Bt1}	0.00	0.01	difference
M_{Bt3} vs M_{Bt1}	0.62	0.10	No difference
M_{Dt3} vs M_{Bt1}	0.86	0.86	No difference

To ensure that comprehensive lab work type is appropriate, a model match analysis is performed with the structural equation model (SEM). The results of the analysis are presented in Figure 2. Figure 2 presents the results of the SEM analysis. The main criteria for the fit model are RMSEA< 0.08 and $\chi 2 > 0.05$. It is known that the model has fulfilled the fit criteria. This suggests that the comprehensive lab work type has been empirically tested as it has a match against HOTS and scientific attitudes.

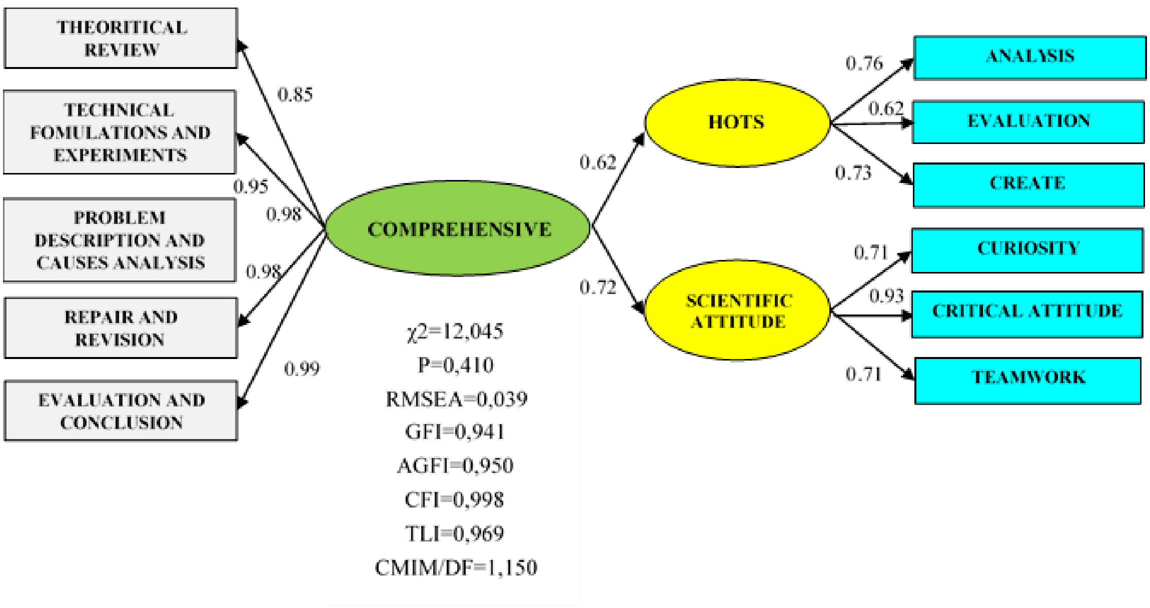

Figure 2. SEM analysis results

DISCUSSION

The comprehensive lab work type consists of seven steps, namely: theoretical review, technical formulation, experimentation, description of problems, search the cause, repair and revision, evaluation, and conclusion. Each step or stage developed specifically to be able to improve the scientific attitude and HOTS. In the theoretical review, students study concepts related to the topic of the experiment to be experimented with and how to use the apparatus. At this stage, a sense of curiosity, critical attitudes, and analytical skills are needed to understand how the apparatus works and uses. Afterward, it is followed by technically formulate apparatus configuration. At this stage, students prepare the necessary apparatus and materials, calibrate the measuring instrument and assemble the experimental apparatus and materials. Curiosity, critical attitudes, cooperation, and analytical skills are required to technically formulate a series of apparatus and materials to be used in practicum.

Once the technical formulation is complete, further enter at the experimental stage. The experiments using Arduino with voltage and current sensor modules as electrical measuring devices. Arduino-based measuring instruments and sensors as a measuring model. In its use, knowledge of electrical concepts is needed which includes how to measure current and voltage, Ohm's Law, also series and parallel resistance circuits as a physical system model. At the measurement process, there is good cooperation to obtain valid data and to streamline the time for the lab work to run on the target. During data, retrieval will appear student critical attitude. Students need a critical attitude to get accurate experiment results. In the process of measuring, the data taken sometimes shows a distorted pattern so that it takes a critical attitude and good cooperation in the analysis of the problem description that will then be searched for the cause of the problem. Analysis and evaluation are done to check if the appliance has been functioning properly so that it gets accurate data that leads to the right conclusion. The result of the Arduino is further compared with the manual measuring instrument, which is multimeter.

The in conformity of measuring results between Arduino and Multimeter will lead students to find the problem. critical attitudes, curiosity, cooperation, analytical skills, and evaluation are needed to find them and search for causes. After the cause of the problem is found, students do repair and revision according to their respective reasoning. At the stage of repair and revision of all the ability of high order thinking and scientific attitude required. In this step comes the model-based reasoning component in the form of revision of understanding related to technical guidance, revision of technical formulation, revision of problem description, revision of measurement model, repair of the measurement device, revised system physical of the device, physical system model revision, and revised how to evaluate. Evaluation is done to check the correct repair and revision activities. In the final stage, conclusions are referred to the results of the experiment.

The elucidation to the learning stages of the comprehensive lab work type has been in accordance with student characteristics and physics material to improve the HOTS and scientific attitudes of students. It is supported by a model match test by using SEM so that it can be concluded that the comprehensive lab work type has been empirically proven in improving HOTS and scientific attitude. The comprehensive lab work type using the Arduino is capable of delivering modeling that can stimulate student reasoning so that it can lead to improved HOTS and student scientific attitudes. The use of Arduino and sensors as a measuring instrument will stimulate the student reasoning in the practicum, due to the use of this apparatus requires logic in coding the program and skills in arranging the apparatus and taking measurements. Arduino in this study is used as a model representing the concept of electricity. This was in line with the study of Heijnes, Van Joolingen & Leenaars (2018), which found that student reasoning was stimulated by presenting models, modeling and teaching media. The study by Louca, Zacharia & Constantinou (2011), Malone, Schunn & Schuchardt (2018), suggests that modeling in learning contributes to improved cognitive, metacognitive and social abilities.

The comprehensive lab work type proved to be effective, it can be seen from the results of lab work implementation. The effectiveness of this type of lab work can be seen from the significant differences in learning outcomes. The test results of Kruskal Wallis show that there is significant HOTS score difference after implementation with the comprehensive lab work type. The student average score taught with the comprehensive lab work type is higher than taught with the deductive type. This suggests that the comprehensive lab work type is effective in enhancing HOTS or have an instructional impact. The findings are supported by Richland & Begolli (2017), Zohar & Alboher Agmon (2018) which shows that reasoning in the lab work is the essence of the HOTS so that the development of HOTS-based learning can foster reasoning and understanding for learners. This is in line with the study of Madhuri, Kantamreddi & Goteti (2012), Hugerat & Kortam (2014), Hopson, Simms & Knezek (2001) who found that collaboration learning, technology-based learning, and investigations in lab work can drive increased HOTS.

The comprehensive lab work type further has an impact on the raising of the student's scientific attitude. The test results of Kruskal Wallis show that there is a significant difference in the scores of scientific attitudes of students in the control and experiment classes. The average score of classes taught with the comprehensive lab work type is higher than with the deductive type. This shows that this type has significantly improved students' scientific attitudes. The results of the study were supported by Romine, Sadler, & Wulff (2017), which suggests that scientific attitudes will change during the study of science and technology-based projects in the laboratory. Furthermore, Palic & Pirasa (2012), and Hugerat & Kortam (2014) showed that laboratory activities could improve positive attitude, creative and critical thinking skills, as well as being able to obtain scientific results and can understand scientific rules. Previous studies have shown that reasoning-based lab work is one of the learning models that can enhance students' positive attitudes in learning science, which is called a scientific attitude.

In detail the results of this development can contribute to the physics education study program in higher education and schools to improve the main competencies of graduates, among others: (1) Able to plan, implement, and assess learning through learning oriented to HOTS mastery by utilizing various learning resources, science and technology-based media, and local environmental potential according to process and quality standards. (2) Mastering scientific methods and attitudes to form an integrated knowledge system that integrates between physics concepts and physics experimentation. (3) Mastering the theoretical concepts of learning and other knowledge concepts that support the competence of physics teachers, specifically the measurement techniques with the microcontroller (Arduino). To follow up on this study as further product development efforts, it is recommended that some of the following: (1) Analyze the theory and explore the information in depth so that the resulting products can be better. (2) Applying models to lectures more broadly not only on lab work activities (practicums). (3) Explore other aspects of scientific attitudes relevant to the comprehensive lab work type. (4) Examines more in-depth reasoning of students towards models presented in the laboratory using Arduino and sensors as a measurement model and further using other advanced equipment.

CONCLUSION

Based on the results and discussion, it is concluded that the hydrostatic The comprehensive laboratory work is the best type that can be applied according to the demands of competence in the era of the industrial revolution 4.0. This model presents stages of learning that can develop students' reasoning through the Arduino measurement model. This model is in accordance with the cognitive development of students who already have the ability to think to solve complex and abstract problems. This result is supported by the results of the implementation of the model in learning physics. The implementation of comprehensive lab work type is most significant to promote the HOTS and scientific attitudes of physics education students refer to the *Kruskal Wallis* test and the SEM test.

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