



Model-Based Reasoning in the Deductive Laboratory Work with Arduino and Sensor Module

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Abstract

Laboratory work that has been applied so far is more dominant in deductive laboratory work, but this type of laboratory work is not optimal in stimulating students' reasoning ability. Up to now, model-based reasoning studies on laboratory work have been substantial (especially in measurement and troubleshooting activities) and have not seen overall laboratory activity, including the use of alternative instrumentation such as Arduino and its sensor module. Designing the best laboratory work requires the role of model-based reasoning studies using Arduino devices. A mixed-method research design was used in this study with a theoretical study to obtain a predictive pattern for deductive laboratory work model which was matched with the observations of 50 undergraduate physics education students in laboratory work. Revision activities were shown by students in laboratory work depending on the capabilities of reasoning. The results of this study indicate that revision activities in deductive laboratory work using Arduino can stimulate students' reasoning. Arduino can lead students to explore their thinking and reasoning to solve problems in laboratory work.

Keywords: Arduino; Laboratory Work; Model-Based Reasoning; Sensor Module

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INTRODUCTION

Experiments in the laboratory are part of learning science activities. Higher education involves laboratory work as an important component of the curriculum (Nixon, Godfrey, Mayhew, & Wiegert, 2016; Wilcox & Lewandowski, 2017). Learning science through laboratory work can improve students' competence in cognitive, affective, and psychomotor aspects. Calibration and problem-solving skills in experimental activities can be enhanced through laboratory activities

(Girault, D'Ham, Ney, Sanchez, & Wajeman, 2012). Laboratory work can improve students' attitudes, conception, and skills (Nworgu & Otum, 2013). Skills in obtaining information, manipulation, communication, and creativity can be developed by doing laboratory work (ByBee, 2013).

Laboratory work leads students to do reasoning. Deductive and high-level logical thinking skills are the definition of reasoning. Reasoning is combining imagination (Nworgu & Otum, 2013). Modelling in laboratory work is needed



to integrate reasoning into the experimental process (Zwinkl, Hu, Finkelstein, & Lewandowski, 2015). Reasoning is needed to solve problems and determine the success of laboratory work. Science laboratory work is central to teaching. Laboratory work can be classified into five types, namely science process skills, problem solving, deductive, technical skills, and inductive. These five approaches have differences and characteristics.

Deductive is more often applied to undergraduate students. The deductive laboratory work aims to verify concepts, with a focus on studying theories and proving them through experiments (Nworgu & Otum, 2013). The deductive approach uses the application of theory into practice.

Deductive or verification is a laboratory work that is commonly applied in science to confirm the concepts, principles, and laws that have been studied (Nworgu & Otum, 2013). The deductive approach leads students to develop many concepts. Deductive laboratory work can illustrate the laws of physics. Students study the laws of physics in class, then conduct experiments through investigations to prove concepts.

Abstract concepts in physics can be learned easily through laboratory verification. Through this approach, students are guided to find concepts from the ideas they have. This approach is appropriate for students who are confused about what they are going to do. The teacher guides students by discussing concepts and principles that will be sought through investigation in laboratory work.

Deductive laboratory work that is commonly applied is not yet optimally has an impact on students' abilities as prospective teachers. The lack of teacher skills in physics experiments in the Maluku region was caused by low practicum skills during lectures

(Wattimena, Suhandi, & Setiawan, 2014). As many as 30% of practicum supervisors have poor performance in guiding practicum so that it affects the ability to teach science (Hadiati, Kuswanto, & Rosana, 2018). The ability of students to learn physics is influenced by the ability of teachers to teach and guide practicum, so it is necessary to observe laboratory work activities to find the best type of laboratory work.

As part of laboratory work, A model is a substitute object or representation of a phenomenon (Zwinkl et al., 2015). The empirical practice is not sufficient for finding scientific ideas, so initiation and reasoning are needed (Clement & Rea-Ramirez, 2008). Model-based reasoning is a change from a static model to a dynamic one due to the process of thinking/reasoning in laboratory work. Model-based reasoning is a change in generative representation in science (Nersessian, 2002). Model-based reasoning influences students in scientific discovery (Vosniadou, 2013). Model-based reasoning is interpreted as the students' reasoning against the model presented in the deductive physics lab work.

The development of physics laboratory work is influenced by model-based reasoning studies. Construction, prediction, data interpretation, identification, and revision activities in modeling the measuring instrument systems lead students to be more active and productive (Zwinkl et al., 2015). Model-based reasoning demonstrates problem-solving skills on non-functioning experimental devices in physics lab classes (Dounas-Frazer, Van De Bogart, Stetzer, & Lewandowski, 2016). Modeling triggers students to think and increase professionalism (Lehrer, Horvath, & Schauble, 1994). Effective laboratory work activities are influenced by model-based reasoning, so it is important to study.

The study of model-based reasoning in laboratory work focuses on measurement and problem solving but have not looked at all laboratory work activities (Dounas-Frazer et al., 2016; Zwickl, Finkelstein, & Lewandowski, 2013). This study aimed to describe model-based reasoning with Arduino and sensors. This study reviewed all student activities in deductive laboratory work. The measurement model used Arduino because it was easy to obtain and use in schools. Arduino was used because it has a low price and simple programming language. Arduino is a microcontroller based on the ATmega328 microprocessor (Kubínová & Šlégr, 2015). Arduino has the potential to improve reasoning abilities.

METHOD

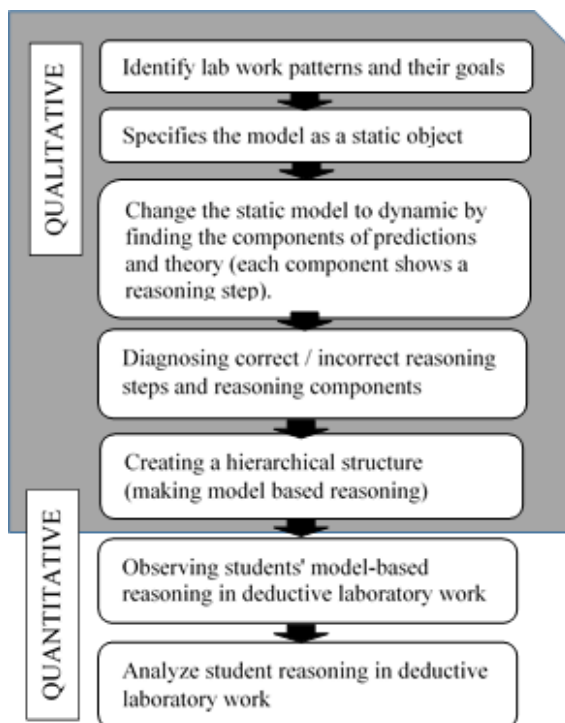


Figure 1 The Phase of The Research

Figure 1 presents the research procedure. Theoretical studies were used to obtain qualitative data. Identification of laboratory approaches and their respective objectives were carried out.

Characteristics of deductive laboratory work were analyzed and illustrated. The component of model-based reasoning is determined based on predictions and theories. This prediction pattern is then matched with observations to obtain quantitative data.

The reasoning step is shown in the component. Observations were made to determine the right and wrong reasoning steps. The troubleshooting process is shown in each component (Dounas-Frazer et al., 2016; Hadiati et al., 2018). The diagnostic model was defined from the components as reasoning. The component showed the individual reasoning steps that must be mastered by students to get the right solution. The components made were adjusted to the facts of observation. Students' reasoning during deductive laboratory work was observed and the essential components were determined so that a model-based reasoning was obtained. The qualitative data obtained are theoretical model-based reasoning, then analyzed descriptively and processed using an interactive analysis model (Miles, Huberman & Saldana, 2014).

Quantitative data were obtained in a deductive practicum using Arduino for three lessons for undergraduate students of the Physics Education program at two Universities in Pontianak when having laboratory work of science.

RESULT AND DISCUSSION

Students' academic ability affects their reasoning so that each student has different reasoning. The use of Arduino modules and sensors in Ohm's law concept provides obstacles for students in carrying out laboratory work, causing reasoning. Figure 2 shows model-based reasoning in deductive laboratory work. The components of model-based deductive reasoning consist of theoretical studies, experiments, and interpretations, conclusions. Laboratory work is completed if the conclusions are

in accordance with the theory, but if there is a discrepancy then revisions are made. The characteristics of model-based reasoning in this type are the revision of theoretical understanding as a result of theoretical studies on deductive laboratory work which commonly applies laboratory work. Class discussions were carried out by the teacher and students were followed by experiments to get concepts and relationships between variables. The discovery of abstract ideas can easily be obtained by deductive laboratory work so that this type has an advantage. With this type, students can find the concept. However, a critical attitude and

teamwork could not be optimized through this laboratory work so that it was considered conventional.

In this deductive practicum, students' reasoning occurred in the activities of revising the Arduino measurement device, revising the measurement model, revising data analysis, revising physical system devices, revising physical system models, and revising theoretical understanding. Each student's problem-solving or revision was different which showed the reasoning. Student reasoning during learning with Arduino is shown in figure 2.

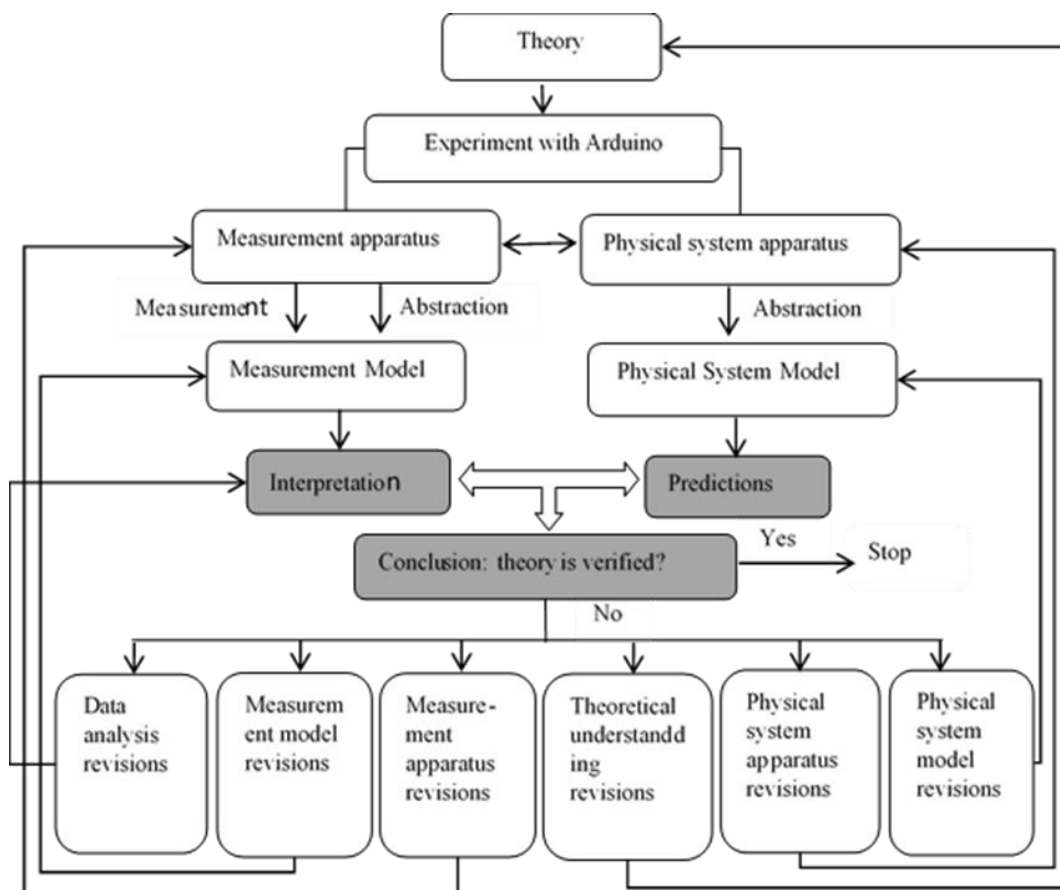


Figure 2 Student's Reasoning on Deductive Lab Work

Figure 3 shows students' reasoning in deductive laboratory work stimulated by the use of Arduino and sensors. This

study involved 50 students, 40% of the students did reasoning by revising the measurement device. Students checked

the functionality of Arduino devices and repaired them if they were damaged. 24% of the students improved the experimental scheme by reanalyzing the measurement model, 14% of the students improved data analysis, 6% of the students reviewed the theory related to the experimental device, 6% of them re-checked the physical system model by reanalyzing the theory, and 10% of them improved their theoretical understanding by looking in other literature. The results showed that students often repair measuring instruments because Arduino requires more complex supporting devices which will cause many technical problems related to the use of the tool. Arduino cannot work alone, so it is necessary to add other components to produce useful applications in designing learning media (Suari, 2017). In addition, Arduino and sensors are rarely used in practicum, so

students need more preparation in using them.

Students' reasoning ability is improved in laboratory work. Experiments using Arduino are highly recommended in learning electrical concepts (Atkin, 2016, 2017; Pereira, 2016) (Atkin, 2016, 2017; Pereira, 2016). The model which was an object representation of physical phenomena in this study was an Arduino and sensor devices. Other physics concepts can be studied using Arduino (Espindola, Cena, Alves, Bozano, & Goncalves, 2018; La Rocca, Riggi, & Pinto, 2020). Models and representations are considered as necessary tools for reasoning (Kind & Osborne, 2017). Cognitive activities that involve reasoning will emerge with the presence of a model (Jacobs, 2017).

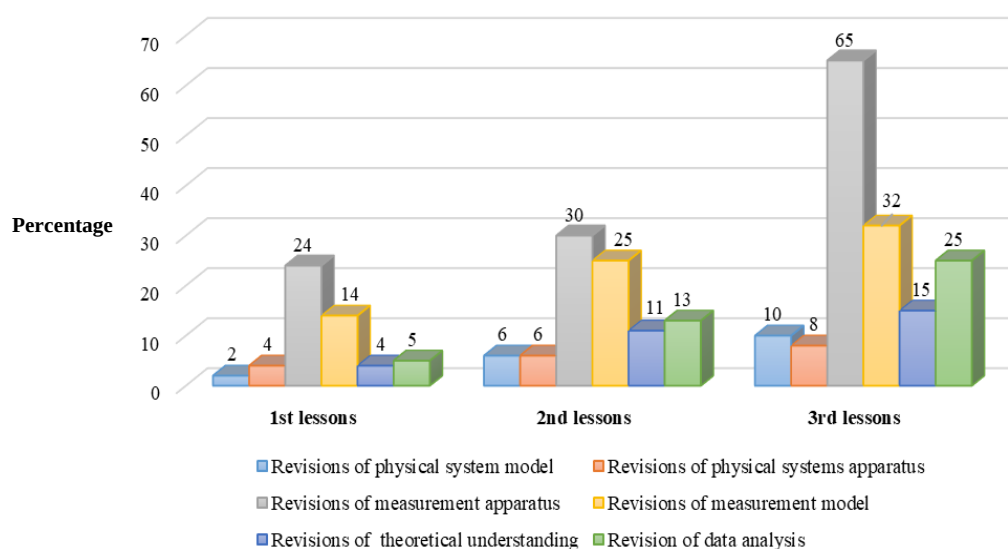


Figure 3. Student Reasoning improves in Deductive Lab Working with Arduino and Sensors

The results of this study indicate that most students did reasoning by revising measuring instruments. A few students did reasoning by revising physical system models and devices. Students who experienced problems

with devices were more likely to replace experimental devices with suspected malfunctions. Students were more suspicious of system problems because Arduino has long durability, so it did not need to be replaced. Problems in

practicum generally arise only due to Arduino and sensor circuit errors, program syntax errors, Arduino and sensor path errors, and the system is unstable so that the sensor readings are not correct. Arduino instrumentation presents interesting problems that can motivate students to solve problems with reasoning so that it is suitable to be used as a tool to develop student abilities.

CONCLUSION

Arduino and sensor instrument in the deductive laboratory work provide a unique experience for students because they are a new experimental system. The selection of different revision steps showed that there were differences in students' reasoning. Arduino instruments in laboratory work cause problems in experiments so that they stimulate students' reasoning to solve problems. Model-based reasoning can provide an overview of education in designing effective laboratory work. Sensors and the internet in laboratory work can be further developed for product development (creativity) through smart labs based on IoT (internet of thinking) to make it more comprehensive.

The limitation of this study was that it had not explored the effect of gender differences in reasoning. Gender affects cognitive abilities related to the reasoning of each individual. Model-based reasoning studies on other types of laboratory work are needed to find the best type of laboratory work that can improve student reasoning.

REFERENCES

- Atkin, K. (2016). Using the arduino with makerplot software for the display of resonance curves characteristics of a series lcr circuit. *Physics Education*, 51(6).
- Atkin, K. (2017). Using the arduino with makerplot software for the display of electrical device characteristics. *Physics Education*, 52(6).
- ByBee, R. W. (2013). *The case for STEM education: Challenges and opportunity*. Arlington: National Science Teachers Association (NSTA) Press.
- Clement, J., & Rea-Ramirez, M. A. (2008). *Model based learning and instruction in science*. Springer.
- Dounas-Frazer, D. R., Van De Bogart, K. L., Stetzer, M. R., & Lewandowski, H. J. (2016). Investigating the role of model-based reasoning while troubleshooting an electric circuit. *Physical Review Physics Education Research*, 12(1).
- Espindola, P. R., Cena, C. R., Alves, D. C. B., Bozano, D. F., & Goncalves, A. M. B. (2018). Use of an arduino to study buoyancy force. *Physics Education*, 53.
- Girault, I., D'Ham, C., Ney, M., Sanchez, E., & Wajeman, C. (2012). Characterizing the experimental procedure in science laboratories: A preliminary step towards student's experimental design. *International Journal of Science Education*, 34(6), 825–854.
- Hadiati, S., Kuswanto, H., & Rosana, D. (2018). Pengembangan Performance Assesment Pada Mata Kuliah Teknik Laboratorium, 8.
- Jacobs, G. J. (2017). Attitudes of pre-service mathematics teachers towards modelling: A south african inquiry. *EURASIA Journal of Mathematics, Science and Technology Education*, 13(1).
- Kind, P., & Osborne, J. (2017). Styles of scientific reasoning: A cultural rationale for science education: Styles of Scientific Reasoning. *Science Education*, 101(1), 8–31.
- Kubínová, Š., & Šlégr, J. (2015). Physics demonstrations with the arduino board. *Physics Education*, 50(4), 472–474.
- La Rocca, P., Riggi, F., & Pinto, C. (2020). Remotely teaching Arduino

- by means of an online simulator. *Physics Education*, 55(6).
- Lehrer, R., Horvath, J., & Schauble, L. (1994). Developing model-based reasoning. *Interactive Learning Environments*, 4(3), 218–232.
- Miles, M. B., Huberman, A. M., & Saldana, J. (2014). Qualitative data analysis: A methods sourcebook.
- Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. In *The Cognitive Basis of Science* (pp. 133–153). Cambridge University Press.
- Nixon, R. S., Godfrey, T. J., Mayhew, N. T., & Wiegert, C. C. (2016). Undergraduate student construction and interpretation of graphs in physics lab activities. *Physical Review Physics Education Research*, 12(1).
- Nworgu, L. N., & Otum, V. V. (2013). Effect of Guided Inquiry with Analogy Instructional Strategy on Students Acquisition of Science Process Skills, *Journal Education and Practice*, 4(27), 35–41.
- Pereira, N. S. A. (2016). Measuring the rc time constant with arduino. *Physics Education*, 51(6).
- Suari, M. (2017). Pemanfatan arduino nano dalam perancangan media pembelajaran fisika. *Natural Science Journal*, 3(1), 474–480.
- Vosniadou, S. (2013). Model based reasoning and the learning of counter-intuitive science concepts. *Infancia Y Aprendizaje*, 36(1), 5–33.
- Wattimena, H. S., Suhandi, A., & Setiawan, A. (2014). Pengembangan perangkat perkuliahan eksperimen fisika untuk meningkatkan kreativitas mahasiswa calon guru dalam mendesain kegiatan praktikum fisika di sma. *Jurnal Pendidikan Fisika Indonesia*, 10(2), 128-139.
- Wilcox, B. R., & Lewandowski, H. J. (2017). Developing skills versus reinforcing concepts in physics labs: Insight from a survey of students' beliefs about experimental physics. *Physical Review Physics Education Research*, 13(1).
- Zwickl, B. M., Finkelstein, N., & Lewandowski, H. J. (2013). The process of transforming an advanced lab course: Goals, curriculum, and assessments. *American Journal of Physics*, 81(1), 63–70.
- Zwickl, B. M., Hu, D., Finkelstein, N., & Lewandowski, H. J. (2015). Model-based reasoning in the physics laboratory: Framework and initial results. *Physical Review Special Topics-Physics Education Research*, 11(2).