25 (1), 2024, 53-65
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

A Study of Fluid Convective Flow in a Room: A Research-Based Learning on Heat Transfer Topics

Gunarjo Suryanto Budi, Theo Jhoni Hartanto*, Fenno Farcis, Umi Amanda Putri & Kristanoval Siloam
Department of Physics Education Program, Universitas Palangka Raya, Indonesia

Abstract: This study is motivated by the importance of developing learning patterns that emphasize the formation and understanding of students through active learning. One form of learning that can support this goal is research-based learning. Research-based learning promotes student-centeredness and integrates research into a meaningful learning process. In this work, the students are actively involved in real research related to fluid convective flow topics. This research aims to describe the impact of research-based learning on students' understanding of convective fluid flow topics. A pre-experimental research method with a one-group pre-test and post-test design was used. Participants were taken from students in the Physics Education Study Program at the University of Palangka Raya taking thermodynamics courses. The number of participants was 20 students. The test instrument is in the form of essay questions consisting of five questions related to fluid convective flow material. The finding indicates that prospective teacher students' understanding was significantly increased with a high category (N-Gain score of 0.74). Based on this study, research-based learning activities could be considered an alternative to conducting meaningful learning activities, especially in fluid convective flow topics.

Keywords: fluid flow, physics learning, research-based learning.

▪ INTRODUCTION

Fluid is a topic that focuses on observing and understanding natural phenomena that occur in the environment. Aliligay et al. (2022) state that the majority of objects in our environment are fluids. Physics' fluids topic focuses on observing and comprehending natural processes that take place in the surrounding world. As a result, knowledge of fluid is required.

Specifically, because of its complexity and scope, teaching and comprehending fluid flow has been judged difficult and boring for a large number of students. In particular, the topic of fluid convection flow is a difficult one for students, apart from conduction and radiation (Pour et al., 2018). Although not fully understood, fluid is a complex subject (Aliligay et al., 2022). According to Xiao (2019), students usually find fluid topics as some of the most difficult because of the abstract nature of fundamental fluid concepts and the extensive mathematical background required to solve fluid problems. The topic of fluids is typically more mathematical and less representational than the more visually appealing flows that are more frequently encountered in daily life. It is not unexpected that students frequently describe these courses as cognitively challenging, visually lifeless, and difficult in terms of math (Hertzberg et al., 2012).

Apart from the characteristics of fluid material, the learning pattern on this topic also creates difficulties. The learning pattern often used by lecturers on fluid flow topics is the conventional lecture method (Cirenza et al., 2018). Traditional lecture methods result in little or no change in most students' understanding of how the physical world works (Musasia et al., 2016). Steward-Wingfield & Black (2005) stated that many

Theo Jhoni Hartanto
*Email: theo@fkip.upr.ac.id

DOI: http://dx.doi.org/10.23960/jpmipa/v25i1.53-65
Received: 03 June 2024
Accepted: 04 July 2024
Published: 17 July 2024

educators when teaching fluid flow topics, place more emphasis on writing formulas and solving problems on the whiteboard and ask students to verify their understanding. Gamez-Montero et al. (2015) and Nantsou et al. (2020) found that many students were less interested in studying the topic of fluid flow because they thought this topic did not see its application or usefulness in life.

Furthermore, this topic has not attracted enough interest from educators, like other physics topics (Vaidya, 2021). Correspondingly, Misbah et al. (2023), through their search from various studies, found that the topic of fluid flow in learning is still little found; fluids are more associated with computational fluid dynamics (CFD) and machine learning and more associated with principal component analysis (PCA), which is applied in engineering.

Under these conditions, instructors must be innovative to foster an engaged learning environment. Learning appears to require something more organized, like hands-on experimentation, practical experience, or mental exercise. According to Cirenza et al. (2018) and Hofstein and Mamlok-Naaman (2007), students following this learning pattern would be expected to provide complete understanding and scientific explanations based on their observational activities. The students' understanding is one of the most important things in the learning process (Phanphech et al., 2019; Duit & Treagust, 2003); in simple terms, Redish & Steinberg (1999) state that understanding physics concepts is an essential part of learning physics. One effort that is considered strategic in making students understand physics concepts is by developing and implementing research-based learning.

According to Usmeldi et al. (2017), research-based learning incorporates research into a meaningful learning process and promotes a student-centered. Real-world challenges provide the foundation for research-based learning, giving students a setting in which to acquire important knowledge and concepts related to the subject while also developing problem-solving strategies and abilities (Hidayatul et al., 2020). Constructivism, which involves four aspects of learning, includes research-based learning. These include learning that involves social interaction processes, learning that involves building prior knowledge, learning that involves students' understanding, and meaningful learning that is attained through practical experience. Research is a crucial tool for improving the quality of learning (Susiani et al., 2018).

Several studies have shown the importance of research-based learning in relation to student understanding and learning patterns. Brew & Saunders (2020) found that research-based learning succeeded in enabling teachers to revitalize their usual learning patterns. Ramahwati (2016) found that research-based learning allows students to practice searching, collecting and processing data, and drawing conclusions, which help them gain a better understanding. Research conducted by Tungkasamit (2019) also found that through research-based learning, students practice conducting investigations of material by finding, proving, collecting, analyzing, and drawing conclusions appropriately following the data collected. Nursofah et al. (2018) and Daryanes & Sayuti (2023) find that research-based learning can construct students' knowledge by practicing through a series of observation and analysis activities. Usmeldi et al. (2017) argue that the implementation of research-based learning is an effective way to improve students' understanding. Furthermore, research by Narahaubun et al. (2020) discusses improving the quality of learning through research-based learning, which provides a good understanding for students.

This article aims to provide an overview of students' understanding of thermodynamics courses, especially on the topic of fluid flow, as a result of implementing research-based learning. Through research experience, students get the opportunity to learn fluid flow topics not only from lecture material but also from research practices, which include literature searches, building hypotheses, collecting data, analyzing and testing data, and drawing conclusions.

▪ METHOD

Research Design and Procedures

This research is pre-experimental research using a one-group pretest-posttest design, which provides treatment to the sample class to determine the changes that occur (Sugiyono, 2019). The research procedures began by conducting the test before implementing the treatment, called the pre-test. It was given to the sample class. After completing the pre-test, the next step is implementing research-based learning. The last stage was a post-test. The test results were analyzed to determine the impact of the treatment by looking at the gain number as an indicator of effectiveness.

Participants

This research was carried out at the Physics Education Study Program, University of Palangka Raya. Treatment in the form of research-based learning was implemented on 20 students taking the thermodynamics course. These twenty students were the samples for this research.

Treatment

The treatment is in the form of applying research-based learning. The research-based learning patterns in this research were adapted from studies conducted by Priantari et al. (2022), Usmeldi (2015), and Usmeldi (2016). The first step of this research-based learning is to identify basic problems related to airflow and air conditioning, or AC, in a room. The second step is an inventory of aspects that support the research process (design an experiment to measure the velocity and pattern of airflow in an air-conditioned room, along with complete equipment and materials). The experimental design was adapted to research conducted by Kenjeres et al. (2005). One of the main differences in this research is that it uses an anemometer, without using CFD like the two previous studies. The equipment used in this research includes one split-type AC unit of a certain brand with 1 PK power, an anemometer (tool sensitivity 0.2 m/s), and a room in the M building of the Physics Education Study Program, University of Palangka Raya, with classroom dimensions of 4 meters (length) x 3.5 meters (width) x 3 meters (height). Data was collected during the day with sunny outdoor weather conditions and without direct solar radiation entering the classroom. Data collection on the airflow velocity in the room was carried out using an anemometer measuring instrument. The room settings used in data collection are shown in Figure 1. Airflow velocity measurements were carried out on the shaded partition walls. Data collection on airflow velocity in the room is carried out at predetermined points, as shown in Figure 2. If you look at Figure 2, the numbering of points in each zone is carried out based on the distance from the wall where the air conditioner is installed.

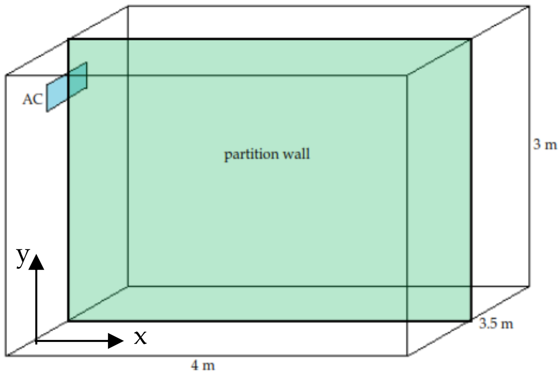

Figure 1. Sketch of the room as a place for data collection

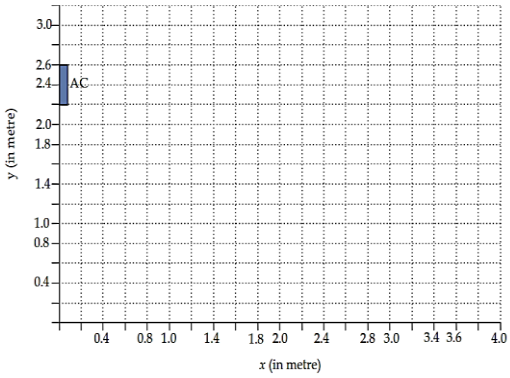

Figure 2. Airflow velocity data collection point

The third step is collecting literature data to understand more deeply the supporting aspects of the research process by searching websites or other relevant media to the research. The fourth step is to carry out data collection activities based on a previously prepared design. At this stage, students (in small groups) carry out experiments, collect data, and analyze the data to answer the problems that were raised at the beginning. Students design a room as in Figure 1, measure air flow velocity using an anemometer in a closed room equipped with air conditioning, draw an airflow velocity vector, and analyze airflow patterns in the room. Student research ends with the final step (fifth step) in the form of reporting the results of research and meta-literacy that have been carried out by students. These steps describe how students carry out the learning process using research-based learning to increase students' understanding of the topic of airflow.

Instrument

Data on students' understanding of convective fluid flow material was obtained using test instruments developed by researchers. The test instrument is in the form of essay questions consisting of five questions related to fluid convective flow material. This test instrument has been validated by experts, consisting of one physics lecturer and one high school teacher. The results show that most of the questions are valid, with a range of very low to very high validity. This test instrument was tested on other students who were not the research sample. The Cronbach's alpha reliability value is 0.63, which is included in the adequate level of reliability (Siswaningsih et al., 2017). Indicators of questions in the test are presented in Table 1.

Table 1. Question indicators in the test

The Indicator of Conceptual Understanding	Question Indicators	Question Number
Explain the concept of convection	**Q1:** Describe the physical motion of the medium by means of the differences between conduction and convection	1
Determine convective occurrences in daily life.	**Q2:** Determine which convection events take place in the nearby environment and describe the mechanism	2

Solving convection problems quantitatively	**Q3:** Determines the convectional heat transfer rate in a fluid given the specified parameters	3
Analyze the convection process	**Q4:** Analyze the variables that affect the convectional heat transfer rate	4
Evaluate the effectiveness of convection	**Q5:** Assess the efficiency of convection in particular technological applications and offer recommendations for enhancements	5

Data Analysis

Data were collected before (pretest) and after (posttest) students participated in the learning. The data obtained was then analyzed using MS Excel for calculations and SPSS IBM version 24 for statistical analysis. Analysis of test results was carried out using a paired t-test to determine whether there were significant differences in the treatment given by researchers (Sudaryono, 2019). Before carrying out the paired t-test, the researcher carried out a normality test first to find out whether the data was normally distributed or not. Then, after calculating the N-gain score to determine the test score improvement category using the N-gain score test, the N-gain score is described through categories in Table 2. The criteria used in determining the interpretation of learning effectiveness are determined using the criteria of Hartanto et al. (2023) in Table 1. Finally, if the data is normally distributed and homogeneous, then the paired sample t-test will be used. Meanwhile, if one of the data points is not normally distributed or homogeneous, the non-parametric Wilcoxon-signed rank test will be carried out.

Table 2. N-gain learning effectivity interpretation (Hartanto et al., 2023)

Mean N-gain	**Students' Understanding Interpretation**
<g> < 0.3	Low
0.3 ≤ <g> ≤ 0.7	Moderate
<g> > 0.7	High

▪ RESULT AND DISSCUSSION

Research-based learning is applied to thermodynamics courses, especially on the topic of airflow. The research-based learning procedures applied in the lesson were adopted from Priantari et al. (2022), Usmeldi (2015), and Usmeldi (2016), including formulating general questions (fundamental problems); inventorying aspects that support the research process (planning research activities, clarifying methods); a collection of literacy data; carrying out data collection activities (conducting investigations); analyzing data; reports; and presentation of results. Meanwhile, the experimental activities were adapted from experiments carried out by Kenjeres et al. (2005).

After the pre-test and post-test were conducted, the data obtained was then calculated and analyzed. The answer to the 20 students is calculated, to sum up the correct answer. The initial understanding of the students obtained from the pre-test was 40.20. Then we can pose an enhancement since the post-test gained 84.20 scores. After the average score was calculated, the normality test, N-Gain test, and nonparametric Wilcoxon signed-rank test were then carried out to further investigate the data more deeply by using SPSS version 24. The results are described in Table 3. The normality test, the pre-test, got sig. 0.04, and the post-test got 0.36. Therefore, since the prerequisite for normally distributed data is a sig. value > 0.05, the pre-test is considered not normally distributed, whereas the post-test was normally distributed. Despite this, a nonparametric test was carried out. The hypothesis test, the Wilcoxon signed-rank test, was implemented. Asymp. sig. (2-tailed) gained was 0.000, which means it suggests that students' understanding was significantly affected after implementing the research-based learning on airflow material since the asymp. sig. (2-tailed) value is less than 0.05. Inevitably, the N-Gain was calculated. The N-Gain score was 0.74, which further classified high efficiency in students' understanding. Specifically, the results of the analysis of each question item are presented in Table 4. Based on Table 4, statistically, it can be seen that there has been an increase in student understanding, as seen from the results of the pre-test and post-test.

Table 3. Statistical data from pre-test and post-test

Component	**Pretest**	**Posttest**
N	20	20
Average score	40.20	84.20
N-Gain	0.74 (category = high)	
Shapiro-Wilk Normality Test		
Signification (sig.α = 0.05)	0.04	0.36
Conclusion	not normally distributed	normally distributed
Wilcoxon signed-rank test		
Signification (sig.α = 0.05)	Asymp. sig. (2-tailed) = 0.000 < 0.05	
Conclusion	There is significant difference	

Table 4. Statistical data from pre-test and post-test on each question

Component	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Average scoer Pre-test	6.85	6.65	9.85	9.45	7.76
Average score Post-test	9.50	13.75	16.20	20.35	24.25
Shapiro-Wilk Normality Test	Pre-test and post-test are not normally distributed			Pre-tests are not normally distributed; Post-tests are normally distributed	Pre-test and post-test are not normally distributed
Wilcoxon signed-rank test	Asymp. sig. (2-tailed) = 0.000 < 0.05: There is significant difference				
N-Gain	0.83	0.85	0.75	0.70	0.63

In addition, the results of the N-Gain analysis for each question item based on the pre-test and post-test are presented in the Table 4 and Figure 3 diagram. Figure 3 shows that the implementation of research-based learning is able to increase students' understanding of the topic of convection fluid flow. The indicator explaining the concept of convection obtained an N-gain of 0.83 (an increase in the high category), the indicator explaining the concept of convection obtained an N-gain of 0.83 (an increase in the high category), the indicator for identifying convection in everyday life obtained an N-gain of

0.85 (an increase in the high category), the indicator for solving convection problems quantitatively obtained an N-gain of 0.75 (an increase in the high category), the indicator for analyzing the convection process obtained an N-gain of 0.70 (an increase in the moderate category), and the indicator for evaluating the convection process obtained an N-gain of 0.63 (an increase in the moderate category).

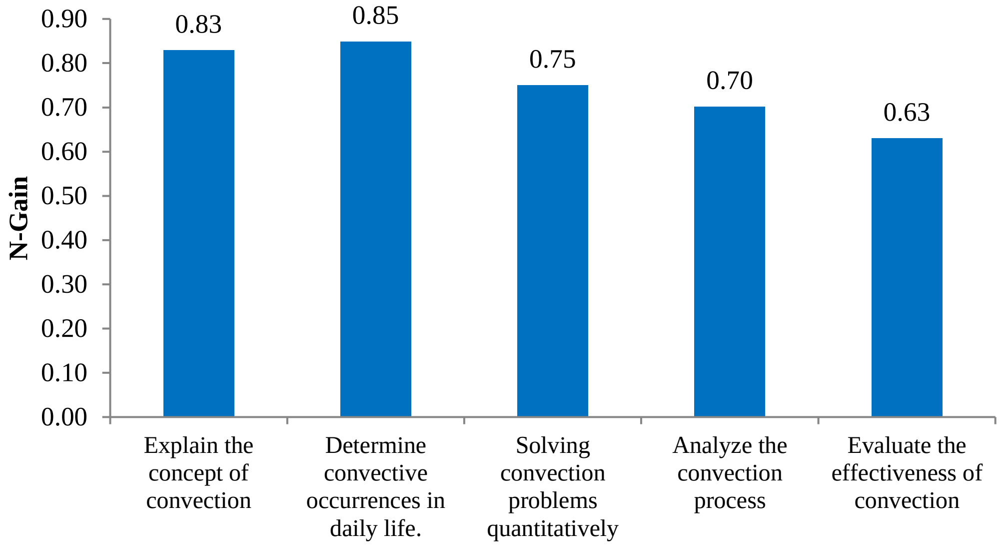

Figure 3. N-Gain gain for each test question

Based on the results of pre-test and post-test data analysis, it can be stated that research-based learning can develop students' cognitive abilities, especially in air flow material. These results are relevant to the results of studies conducted by Usmeldi (2016) and Suyatman et al. (2021), who found that research-based learning is very effective in increasing students' understanding of physics content or science content. In addition, research-based learning can train thinking experiences through thinking habits to form knowledge (Camacho et al., 2017; Srikoon et al., 2014; Lambert, 2009).

The results obtained are closely related to the research-based learning patterns that have been implemented for students in class. The essence of research-based learning is to involve students in real investigative problems by confronting them with investigative methods and asking them to design ways to solve the problem. Through research, students learn to become scientists and gain knowledge. Triyanta (2018) stated that through research-based learning, students are expected to have attitudes like scientists. Research-based learning has characteristics that enable students to practice searching, formulating hypotheses, collecting and processing data, and drawing conclusions, which ultimately can help them gain better understanding and knowledge (Ramahwati, 2016). Therefore, research-based learning is a model that not only increases knowledge but also performance in solving problems through research (Putri et al., 2021; Yanti et al., 2019) and can help students construct physical concepts or principles, making learning more meaningful (Estuhono et al., 2019).

This research shows a glimpse of how research-based learning patterns can train students to provide appropriate scientific explanations based on the results of their observations of a phenomenon in nature. For example, Figure 4 shows the results of student work related to airflow patterns in closed spaces based on the results of measurements using an anemometer. Figure 6 shows that students tried to explain the results they obtained. According to the students, the airflow patterns they observed were related to convection events, which have to do with moving fluids like air. As air is cooled, it contracts, becomes denser and sinks. Warmer air at the bottom is displaced and due to it being less dense, it rises. This process continues and sets up a convection current that will allow thermal transfer to occur. Since cold air is emitted from the air conditioner unit blowers, the unit has to be placed at the top of a room to allow a convection current to form. From this, it can be seen that students are starting to develop arguments and explanations to support the data and observations they have made. Hartanto's (2017) research findings concluded that learning physics accompanied by scientific activities can improve the ability to provide scientific explanations and an in-depth understanding of the natural phenomena that one observes. The experiments in research-based learning allow students to understand the relationship between what is observed (hands-on) and the scientific ideas that underlie their observations (minds-on) (Walker et al., 2019).

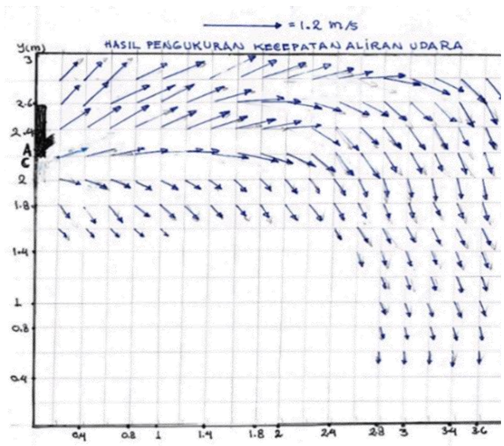

Figure 4. Example of student work on airflow patterns in an air-conditioned room

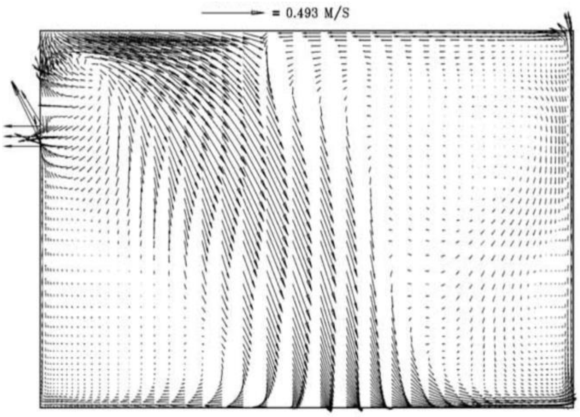

Figure 5. Flow patterns and air velocity in air-conditioned rooms from the results of the study by Kenjeres et al. (2005)

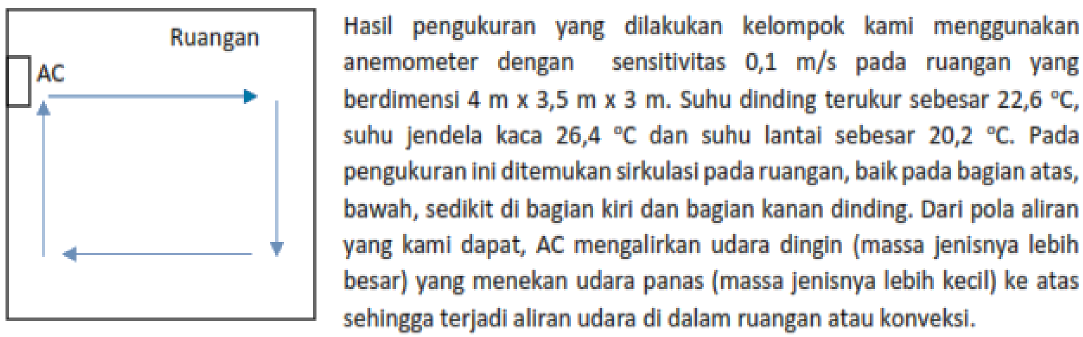

Figure 6. Example of student explanation of the results of airflow patterns

The results of the students' work in Figure 4 show the pattern and speed of airflow in a room that has an air conditioner, resulting from measurements using an anemometer. Meanwhile, Figure 5 shows the results of measurements using CFD carried out by

Kenjeres et al. (2005) and is a reference in this research-based learning. The pattern shown in Figure 5 is the airflow pattern in a refrigerated room with dimensions of 4.2 m x 3.6 m x 2.5 m (almost the same room dimensions as the one designed by the students). The wall temperature is set at 21 °C, the front wall is 22 °C, and the glass window is at 30 °C. As can be seen in Figure 5, the simulation results show the occurrence of a complex flow with several circulations, especially at each corner of the plane, which indicates the presence of turbulence. This complex flow structure is due to the buoyancy effect from the window facing the air conditioner which causes the cold air flow to bend downward when it reaches the middle of the room. Besides that, the reflection of cold air by the ceiling also causes this pattern. A thin air flow along the wall towards the ceiling occurs right in front of the window as a result of the air being stretched by high temperatures. This condition is slightly different from the room conditions in research-based learning carried out by students.

This study highlights the potential of research-based learning to promote collaborative learning activities. Through research-based learning, instructors and students can work together to explore concepts and problems. A community of learners emerges from the classroom (Suyatman et al., 2021). Together with their teacher, students work in groups in the classroom to ask questions, write justifications, draw conclusions, make sense of the material, talk about the facts, and present their results. As they interact with their peers, collaboration enables students to develop a shared understanding of scientific concepts and the nature of the subject. When students collaborate, they have the opportunity to participate in high-quality social interaction that may foster deep learning (Scager et al., 2016; Visschers-Pleijers et al., 2006). Understanding complex concepts and processes in science education requires a deep learning strategy (Van Boxtel, 2000). A process of conceptual change is necessary to understand these ideas, and collaborative learning is one setting in which this process is especially active (Scager et al., 2016).

Another important note from this research is that lecturers play a key role in the success of research-based learning by involving students in the collection and processing of information. Dobber et al. (2017) stated that the teacher's role is very important for the successful implementation of research- or inquiry-based learning. Although teachers sometimes provide information through lectures and textbooks are used as sources of information, there is an emphasis placed on students learning how to search for and process the resources themselves. In research-based classroom learning, the teacher often acts more like a coach, guiding students as they develop questions and problems, helping students to find, read, sort, and evaluate information, giving students opportunities to draw their conclusions, and providing time and opportunities for students to communicate results. The classroom climate and environment continually encourage students to express opinions, solve problems, and think at higher levels. Kudryashova et al. (2016) stated that modern teachers must change their vision of the role of teachers from transmitters of knowledge to multi-role educators who can involve students in the process of acquiring knowledge and developing skills independently.

▪ CONCLUSION

Implementing research-based learning on airflow topics with a sample of twenty students was done. The data analysis revealed that the understanding of students had increased. 40.20 was the pre-test score, while 84.20 was the post-test score. Furthermore, the N-Gain value of 0.74 showed that the students' understanding had significantly improved. The analysis of the mean scores shows that there is a statistically significant difference between the pre-test and post-test scores. Overall, it was found that using research-based learning to increase students' understanding was successful.

The current study's findings highlight the potential of research-based learning. Through active learning, research-based learning gave students the chance to connect the theoretical concepts they had learned in class to real-world applications, which gave the learning process greater purpose. Students also got the chance to learn leadership skills and become proficient researchers and organizers when working in groups. However, this study still requires a lot of improvement, mainly because it is limited to one heat transfer mechanism and uses equipment that can be said to be very simple. In the future, it is necessary to expand the material content and equipment used to support research-based learning to improve the quality of learning outcomes and the quality of study.

▪ REFERENCES

Aliligay, M. D. S., Rendon, J. D. L., Villarias, C. J. R., & Mercado, J. C. (2022). Strategies in learning fluid mechanics: a literature review. International Journal of Multidisciplinary: Applied Business and Education Research, 3(8), 1556-1563.

Brew, A., & Saunders, C. Making sense of research-based learning in teacher education. Teaching and Teacher Education, 87, 102935.

Camacho Rivadeneira, M. H., Valcke, M., & Chiluiza Garcia, K. The effect of “research based learning activities” on students’ intention to do research in graduate courses. In L. Chova, A. Martinez, & I. Torres (Eds.), 9th international conference on education and new learning technologies (edulearn17,) 6571–6579.

Cirenza, C. F., Diller, T. E., & Williams, C. B. Hands-on workshops to assist in students' conceptual understanding of heat transfer. Journal of Heat Transfer, 140(9), 092001.

Daryanes, F., & Sayuti, I. Research-based learning in biology courses to train students critical thinking skills: Student’s perception. Biosfer: Jurnal Pendidikan Biologi, 16(1), 124-137.

Dobber, M., Zwart, R., Tanis, M., & van Oers, B. Literature review: The role of the teacher in inquiry-based education. Educational Research Review, 22, 194-214.

Duit, R., & Treagust, D. F. Conceptual change: A powerful framework for improving science teaching and learning. International journal of science education, 25(6), 671-688.

Estuhono, Festiyed, & Bentri, A. Preliminary research of developing a research-based learning model integrated by scientific approach on physics learning in senior high school. In Journal of Physics: Conference Series (Vol. 1185, No. 1, p. 012041). IOP Publishing.

Gamez-Montero, P. J., Raush, G., Domenech, L., Castilla, R., Garcia-Vilchez, M., Moreno, H., & Carbo, A. Methodology for developing teaching activities and materials for use in fluid mechanics courses in undergraduate engineering programs. Journal of Technology and Science Education, 5(1), 15-30.

Hartanto, T. J. *Pembelajaran ipa pada konsep kalor yang berorientasi doing science* [science learning oriented to doing science on the concept of heat] Jurnal Fisika Indonesia, Vol 21, No 2, 12-19.

Hartanto, T.J., Dinata, P.A.C., Azizah, N., Qadariah, A., & Pratama, A. Students' science process skills and understanding on Ohm's law and direct current circuit through virtual laboratory based predict-observe-explain model. Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 11(1):113-128.

Hertzberg, J., Leppek, B. R., & Gray, K. E. Art for the sake of improving attitudes toward engineering. In 2012 ASEE Annual Conference & Exposition, San Antonio – Texas, 10.18260/1-2--20966.

Hidayatul, M., Tirta, I. M., Wangguway, Y., & Suni, D. M. O. (2020). The implementation of research based learning and the effect to the student metacognition thinking skills in solving H-irregularity problem. Journal of Physics: Conference Series (Vol. 1538, No. 1, p. 012113). IOP Publishing.

Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: the state of the art. Chemistry education research and practice, 8(2), 105-107.

Kenjereš, S., Gunarjo, S. B., & Hanjalić, K. Contribution to elliptic relaxation modelling of turbulent natural and mixed convection. International Journal of Heat and Fluid Flow, 26(4), 569-586.

Kudryashova, A., Gorbatova, T., Rybushkina, S., & Ivanova, E. Teacher’s roles to facilitate active learning. Mediterranean Journal of Social Sciences, 7(1), 460-466.

Lambert, C. (2009). Pedagogies of participation in higher education: a case for research-based learning. Pedagogy, Culture & Society, 17(3), 295-309.

Misbah, M., Hamidah, I., Sriyati, S., & Samsudin, A. Research trend of dynamic fluid in learning: a bibliometric analysis. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 9(2).

Musasia, A. M., Ocholla, A. A., & Sakwa, T. W. Physics practical work and its influence on students' academic achievement. Journal of Education and Practice, 7(28), 129-134.

Nantsou, T., Frache, G., Kapotis, E. C., Nistazakis, H. E., & Tombras, G. S. Learning-by-doing as an educational method of conducting experiments in electronic physics. In 2020 IEEE Global Engineering Education Conference (EDUCON), 236-241.

Narahaubun, S. S., Rehena, J. F., & Rumahlatu, D. (2020). Empowering students’ critical thinking skills, information literacy and cognitive learning outcome through RBL-TPS model. Jurnal Pendidikan Biologi Indonesia, 6(2), 243-256.

Nursofah, N., Komala, R., & Rusdi, R. The effect of research-based learning model and creative thinking ability on students learning outcomes. Indonesian Journal of Science and Education, 2(2), 107–112.

Phanphech, P., Tanitteerapan, T., & Murphy, E. Explaining and enacting for conceptual understanding in secondary school physics. Issues in Educational Research, 29(1), 180-204.

Pour, N. B., Thiessen, D. B., & Van Wie, B. J. Improving student understanding and motivation in learning heat transfer by visualizing thermal boundary layers. International Journal of Engineering Education, 34(2A), 514-526.

Priantari, I., Suratno, S., Wahyuni, D., & Dafiq, D. Stem Education and Research-Based Learning Activities on Taste Roasted in Coffee. M. Fadilah et al. (Eds.): IcoBioSE 2021, ABSR 32, pp. 500–511.

Putri, L. A., Permanasari, A., Winarno, N., & Ahmad, N. J. Enhancing students' scientific literacy using virtual lab activity with inquiry-based learning. Journal of Science Learning, 4(2), 173-184.

Ramahwati, S. Application of research–based learning (RBL) model with scientific approach in improving IPS learning in class V SDN 1 Sukomulyo academic year 2015/2016. Journal of Scholars/ Jurnal Kalam Cedikia, 4(1), 1–19.

Redish, E. F., & Steinberg, R. N. (1999). Teaching physics: Figuring out what works. Physics Today, 52(1), 24-30.

Scager, K., Boonstra, J., Peeters, T., Vulperhorst, J., & Wiegant, F. Collaborative learning in higher education: Evoking positive interdependence. CBE—Life Sciences Education, 15(4), ar69.

Siswaningsih, W., Firman, H., & Khoirunnisa, A. Development of two-tier diagnostic test pictorial-based for identifying high school students misconceptions on the mole concept. In Journal of Physics: conference series (Vol. 812, No. 1, p. 012117). IOP Publishing.

Srikoon, S., Bunterm, T., Samranjai, J., & Wattanathorn, J. Research synthesis of research-based learning for education in Thailand. Procedia-Social and Behavioral Sciences, 116, 913–917.

Sudaryono. *Metodologi penelitian.* Depok: PT Raja Grafindo Persada.

Sugiyono. *Metodelogi Penelitian Kuantitatif dan Kualitatif dan R&D.* Bandung: Alfabeta.

Susiani, T. S., Salimi, M., & Hidayah, R. Research-based learning (RBL): How to improve critical thinking skills? SHS Web of Conferences, 42, 1–6.

Suyatman, Saputro, S., Sunarno, W., & Sukarmin. The implementation of research-based learning model in the basic science concepts course in improving analytical thinking skills. European Journal of Educational Research, 10(3), 1051-1062.

Triyanta. *Pembelajaran berbasis riset pada kuliah fisika dasar di itb sebagai sebuah contoh pendidikan stem. Proceedings of simposium nasional inovasi dan pembelajaran sains* (SNIPS 2018), ITB Ganesha Bandung, 468-475.

Tungkasamit, A. (2019). The effect of using research-based learning model in history practicum in school course. Pedagogia: Jurnal Pendidikan, 8(1), 9-17.

Usmeldi, Amini, R., & Trisna, S. (2017). The development of research-based learning model with science, environment, technology, and society approaches to improve critical thinking of students. Jurnal Pendidikan IPA Indonesia, 6(2), 318–325.

Usmeldi, U. (2016). *Pengembangan modul pembelajaran fisika berbasis riset dengan pendekatan scientific untuk meningkatkan literasi sains peserta didik.* Jurnal Penelitian & Pengembangan Pendidikan Fisika, 2(1), 1-8.

Usmeldi. (2015). The effectiveness of physics based research in learning engineering physics. Indonesian Journal of Science Education, 4(1), 79-85.

Vaidya, A. (2021). Contributions to the teaching and learning of fluid mechanics. Fluids, 6(8), 269.

Van Boxtel, C., Van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. Learning and instruction, 10(4), 311-330.

Visschers-Pleijers, A. J., Dolmans, D. H., De Leng, B. A., Wolfhagen, I. H., & Van Der Vleuten, C. P. (2006). Analysis of verbal interactions in tutorial groups: a process study. Medical Education, 40(2), 129-137.

Walker, J. P., Van Duzor, A. G., & Lower, M. A. (2019). Facilitating argumentation in the laboratory: The challenges of claim change and justification by theory. Journal of Chemical Education, 96(3), 435-444.

Wingfield, S. S., & Black, G. S. (2005). Active versus passive course designs: The impact on student outcomes. Journal of Education for Business, 81(2), 119-123.

Xiao, G. (2019, August). A Study on the bridging strategy between the theory of fluid mechanics and engineering applications. In 2019 International Conference on Modeling, Simulation and Big Data Analysis (MSBDA 2019), 230-235.

Yanti, F. A., Kuswanto, H., & Rosa, F. O. (2019). Pre-service physics teachers' research activities by research-based learning. Journal of Turkish Science Education, 16(1), 77-84.