The Impacts of the Stem-Based Inquiry Learning Models on Critical Thinking and Concept Mastery

EVI YUPANI[1] AND I WAYAN WIDANA[2*]

Abstract

This research aimed to determine differences in critical thinking skills and mastery of science concepts between students who followed the STEM-based inquiry learning model and students who follow expository learning. The population in this research was 209 students in a total sample of 81 students determined through a random sampling technique. Critical thinking data were collected by tests, while the concept mastery data were collected by multiple-choice tests. Data were analyzed using MANOVA. The results of the data analysis showed that the value of F was 26.848 with a significance value of 0.000 which was less than 0.05. Therefore, there are differences in critical thinking skills and mastery of concepts between students who study STEM-based inquiry learning models and students who study expository learning models.

Keywords
concepts mastery, critical thinking skills, learning models, STEM-based inquiry

Article History
Received 13 March 2023
Accepted 10 June 2023

How to Cite
Yupani, E. & Widana, I. W. (2023). The impacts of the stem-based inquiry learning models on critical thinking ability and concept mastery. *Indonesian Research Journal in Education |IRJE|*, *7*(1), 171 – 184. https://doi.org/10.22437/irje.v7i1.24227

[1] Teacher at SDN 3 Pujungan, Bali, Indonesia
[2*] lecturer at PGRI Mahadewa Indonesia University, Bali, Indonesia, corresponding email: iwayanwidana@mahadewa.ac.id

Introduction

Education is one of the paramount needs in human life that has an immense role in the welfare of human life itself. Through the experience and education gained, humans can solve problems, have the readiness to face various challenges in the future, and the growing progress of science and technology (Hidayat et al., 2021; Mukminin et al., 2022; Sofwan et al., 2021) . In the 21st century, students are required to be able to understand sciences, master metacognitive skills, innovate, be able to communicate and collaborate and think critically (Mirayani et al., 2021). Critical thinking is the ability to think logically, reflectively, systematically, and productively which is applied in making judgments and decisions (Hidayah et al., 2017). Critical thinking is also interpreted as activating the ability to analyze and evaluate evidence, identify various questions, and build logical conclusions (Facione, 2015). A critical thinker must have the standard elements in solving problems, which is abbreviated as FRISCO, namely Focus, Reason, Inference, Situation, and Clarity, to solve a problem which is a list of reasonable critical thinking (Ennis, 2015).

In addition to critical thinking skills, some aspects are no less important in achieving quality learning, namely concept mastery. Concept mastery is the ability of students to understand various concepts and theories as well as scientific meanings to solve problems and understand a new concept (Dahar, 2011). Concept mastery can also be interpreted as one of the intellectual abilities related to a student's cognitive abilities, that the intellectual abilities referred to are related to someone's mastery of the environment through ideas (Maknun, 2015). Students who have a good mastery of concepts can develop this ability to apply facts, scientific concepts, principles, laws, and theories used by scientists to explain and predict observations from nature or provide interpretations and be able to apply them in solving a problem (Knaggs & Schneider, 2012).

Currently, critical thinking skills and mastery of concepts are seen as very important to be trained and developed for students (Lestari et al., 2021). It aims to make students accustomed to having critical and deep thinking. Students are also able to apply concepts to various things, be innovative, full of new ideas, be creative, and be sensitive to all opportunities to produce people who have high competitiveness in facing the era of the industrial revolution 4.0 (Susmariani et al., 2018). STEM (Science, Technology, Engineering, and Mathematics) based inquiry learning model can be an alternative to achieving the expected quality of learning.

The STEM-based inquiry learning model has the potential to provide meaningful learning. Learning with this model can train students' ability to solve problems by finding their concepts, facts, or principles that are integrated with one or several other scientific fields, such as science, engineering, and technology. In addition, the STEM-based inquiry learning model can certainly increase collaboration, train critical thinking skills and creativity, and provide students with the experience that science is of real benefit to life and those around them. All of the above will certainly impact satisfactory student learning outcomes.

Literature Review

In the era of the industrial revolution 4.0, critical thinking skills and mastery of concepts are seen as very important to be trained and developed for students. With the ability to think critically and master concepts well, students will get used to having critical thinking, the ability to apply concepts, be innovative, and be sensitive to all opportunities that exist to produce people with high competitiveness in facing the era of the industrial revolution 4.0. (Habibi, Sofyan, & Mukminin, 2023; Habibi et al., 2022; Mukminin et al., 2023; Velasco, Ibarra, & Mukminin, 2022; Rakimahwati et al., 2022; Susanti, Hadiyanto, & Mukminin, 2022). The factual condition of education today is not under what is the primary goal. The results of a survey conducted by PISA (Program for International Student Assessment) in 2018 showed that for the science performance category, Indonesia was ranked 9th from the bottom (71) with an average score of 396 (Tohir, 2019). Likewise, the achievement of educational goals in schools, especially in science learning, is still far from what was expected.

As was the result of observations made in several elementary schools in the Pupuan District, in learning science, students tend to memorize information and not develop their ability to think critically and systematically. The ability to think critically and master students' concepts are still relatively low because the science learning components used in several elementary schools still use a direct approach which is dominated by lecture methods and assignments, so students experience difficulties in developing their abilities according to 21st-century solutions. Science learning in elementary schools should teach students to hone critical thinking skills, form scientific attitudes and have the desire to solve problems.

Concerning the description above, the STEM (Science, Technology, Engineering, and Mathematics) Based Inquiry Learning model can be an alternative to achieving the expected quality of learning (Widana et al., 2021). The inquiry learning model emphasizes how to search and find answers to questions that are questioned own self through a critical and analytical thinking process (Wibawa, 2020). Inquiry means a series of student learning activities in finding and investigating various problems so that students can formulate their findings confidently and involve all students' abilities systematically, logically, critically, and analytically (Kodir, 2018). The syntax of inquiry, in general, is a) orientation, b) determining or formulating problems, c) formulating temporary conjectures that need to be proven true (hypotheses), d) conducting experiments, e) conducting analysis, f) making conclusions (Kurniasih & Sani, 2015).

STEM (Sciences, Technology, Engineering, and Mathematics) is a learning approach that combines four main areas in education, namely science, technology, mathematics, and engineering that requires students to become confident innovators, problem solvers, and inventors (Azura & Octarya, 2020). National Research Council (2014) defined each of the four STEM disciplines as (1) science is a collection of knowledge that has been accumulated over time by a process of scientific inquiry that produces new knowledge, (2) technology is a whole system of people, organizations, knowledge, processes and devices which then create technology to meet their needs or desires, most of the modern technology is a product of science and engineering, (3) engineering is a collection of knowledge about the design and creation of objects man-made and a process for solving problems. Techniques utilize concepts in science, mathematics, and technological tools, (4) Mathematics is the science of patterns and relationships between numbers, numbers, and space. Mathematics is used in science, engineering, and technology. STEM is an integration of technology and techniques applied in science/mathematics learning content that can make students have a different mindset and develop critical power or critical thinking skills (Sandi, 2021).

The STEM-based inquiry learning model can train students' ability to solve problems. Students will discover concepts, facts, or principles for themselves that are integrated with one or several other scientific fields, such as science, engineering, and technology. With the STEM-based inquiry learning model, students will be trained to develop their critical thinking skills, provide meaningful learning, can increase collaboration, and be creative.

Several research results related to the above have been done before, finding that STEM-based inquiry can improve students' critical thinking skills (Islamyah et al., 2018). Likewise, research by Soros et al. (2018) showed that the application of STEM improves students' critical thinking skills and problem-solving (Soros et al., 2018). Meanwhile, the results of research by Anggareni et al. (2013) showed that inquiry learning is proven can improve conceptual understanding and foster students' critical thinking skills so that it is good to apply in further learning.

Methodology

This type of research is quasi-experimental. The population used in this research was all fifth-grade elementary school students in Cluster II and IV Pupuan District, Tabanan Regency, consisting of 10 classes with total students of 209. To determine whether yes or not the abilities of fifth-grade students at each elementary school were equivalent, an equivalence test was carried out with One-Way Anova assisted by SPSS 26.0 for Windows, where the calculation results obtained an F count of 0.544 with a significance of 0.841. Therefore, all classes in this research were declared to have equal abilities.

The sampling technique used in this research is random sampling, where samples are taken randomly from the population through the drawing stage (Widana & Muliani, 2020). The random sample is class. Of the ten classes in *Gugus* II and IV Pupuan District, a draw was carried out to take two classes for research subjects. After drawing lots, SDN 1 Pujungan and SDN 6 Pujungan were chosen as research samples for a total of 81 students. The two classes were drawn again to determine the experimental and control class. From the drawing of the two classes, SDN 6 Pujungan was chosen as the experimental class, while SDN 1 Pujungan was the control class.

The instrument used for critical thinking skills is a description test, and the type of instrument for mastering concepts is in the form of multiple-choice tests. Before the questions were used, the test was first tested. The test results were then analyzed for validity, reliability, internal consistency of item difficulty level, and discriminatory power. For the critical thinking ability instrument, the results of the content validity test showed that the critical thinking ability test used was very high, and the internal test results for item consistency showed that the ten items tested were valid, with the reliability of the critical thinking ability test was relatively high. Likewise, in the concept mastery instrument, where the number of respondents was 36 students, 30 valid test items were obtained. The tests tested included very high-reliability criteria, the test results for the difficulty level of test items from 25 test items. There were 22 test items including medium criteria, and 3 test items easy. Then the results of the discriminatory power of the 25 test items were 20 test items including sufficient and five test items were good criteria.

The data collected were tabulated with the mean and standard deviation related to critical thinking skills and mastery of concepts. To test the hypotheses that have been formulated, data analysis was first carried out in the description, prerequisite testing, and hypothesis testing.

Descriptive analysis was carried out by finding the mean (M), Mode (M0), Median (Md), and standard deviation (SD) values of each variable studied. The assumption test performed includes the normality test of data distribution and the homogeneity of variance test. Test the normality of data distribution for each group using the Kolmogorov-Smirnov formula at a significance of 0.05 with the help of SPSS-26.00 for windows. Homogeneity testing was carried out by testing the similarity of the covariance variants using SPSS-26.00 for windows through the Box's M test for homogeneity tests together and Levene's test for homogeneity tests separately.

To test the first hypothesis using One-Way analysis of variance ANOVA through statistical variance (F) with the help of SPSS 26 for windows, Hypothesis II testing uses a One-Way analysis of variance ANOVA through statistical variance using the SPSS 26 For Windows program. To test Hypothesis III, research data will be processed using multivariate analysis of variance (MANOVA), with a significance level of $\alpha = 0.05$. Tests between subjects were carried out on the significant number of the Pillai's Trace F statistic, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. Testing will be carried out using the SPSS 26 For Windows program.

Findings and Discussion

The data obtained in this research were data on critical thinking skills and mastery of science concepts from a group of students who took the STEM-based inquiry learning model (Science, Technology, Engineering, and Mathematics) and a group of students who took the expository learning model. The average score of students' critical thinking ability data who took part in learning with the STEM-based inquiry learning model was 50.53 at intervals of $50.42 < X \leq 52.25$ and included in the "high" category. The results of the data analysis on mastery of the concept with the STEM-based inquiry learning model for 41 students obtained an average score of 21.51 at intervals of $20.92 < X \leq 22.08$. Overall, the experimental class is included in the "medium" category. Furthermore, an analysis of data on students' critical thinking skills using expository learning obtained an average score of 44.87 at an interval of $43.25 < X \leq 45.75$ included in the "medium" category. The results of the data analysis of students' conceptual mastery following expository learning obtained an average score of 20.27 at intervals of $19.33 < X \leq 20.67$, so the students' conceptual mastery following the expository learning model is included in the "medium" category.

Data distribution normality test

The results of the Kolmogorov-Smirnov test obtained the calculated value of each variable, namely 0.182; 0.164; 0.194; 0.085. All Kolmogorov-Smirnov statistical variables are more than 0.05. Thus, all data distribution is normally distributed.

Variance homogeneity test

Homogeneity testing was carried out by testing the similarity of the covariance variants using Box's M test to test the homogeneity with Levene's test to test the homogeneity separately with SPSS-26.00 for windows. With the criteria, if the significance value is more than 0.05, the data group is declared homogeneous. Conversely, the data group is non-homogeneous if the significance value produced in Levene's and Box's M test is less than 0.05.

The results of the Box's M test analysis obtained sig. 0.535, and Levene's test results obtained critical thinking skills of 0.173 and mastery of concepts of 0.572. Based on the test results, the resulting significant figures together and individually are more than 0.05. Thus, it means that the variance-covariance matrix for the variables of students' critical thinking skills and mastery of concepts is homogeneous.

Hypothesis test 1

The results of the hypothesis 1 test showed that the critical thinking skills of students who took part in the STEM-based inquiry learning model and students who took the expository learning model produced an F value of 52.608 with a significance of 0.000 <0.05. It means Ho is rejected, and H1 is accepted. In other words, there are differences in critical thinking skills between students who follow STEM-based inquiry learning models and students who follow expository learning models.

Hypothesis test 2

The results of the One-Way ANOVA analysis of students' concept mastery data with SPSS 26.00 for windows show that there are differences in concept mastery between students who follow the STEM-based inquiry learning model and students who follow the expository learning model, resulting in an F value of 6.951 with a significance of 0.000 <0, 05. It means H0 is rejected, and H1 is accepted. In other words, there are differences in the mastery of concepts between students who follow STEM-based inquiry learning models and students follow follow expository learning models.

Hypothesis test 3

Furthermore, to find out the differences in critical thinking skills and conceptual mastery of students who study with the two learning models, an analysis is carried out using

MANOVA with SPSS 26.00 for Windows. A summary of the analysis using MANOVA is in Table 1.

Table 1. *Summary of analysis results of students' critical thinking ability and mastery of concepts with MANOVA*

Effect	Statistics	F	Sig.
Learning Model	*Pillai's Trace*	26,848	0,000
	Wilks' Lambda	26,848	0,000
	Hotelling's Trace	26,848	0,000
	Roy's Largest Root	26,848	0,000

Based on the table above, F is 26.848 with a significance value of 0.000 which is less than 0.05. It means H0 is rejected, and H1 is accepted. In other words, simultaneously, there are differences in critical thinking skills and mastery of concepts between students who follow STEM-based inquiry learning models and students who follow expository learning models. These results simultaneously indicate that the student's critical thinking skills and concept mastery who take part in learning using the STEM-based inquiry learning model are better than students who follow the expository learning model.

Differences in critical thinking ability between students who follow the STEM-based inquiry learning model and students who follow the expository learning model

Science learning which is carried out on a STEM-based has made students active, creative, critical, and able to develop their soft skills, provide meaningful learning and train students to solve problems by finding their own concepts, facts, or principles that are integrated with one or several scientific fields, such as science, engineering, and technology, increasing collaboration, and training critical thinking skills. In the initial step of this model or problem orientation, students need to formulate problems and propose hypotheses related to indicators of critical thinking, namely understanding the questions given. Students understand the orientation of finding, formulating problems, or submitting hypotheses. In planning problem-solving and experiments related to critical thinking indicators, namely providing reasons based on relevant facts or evidence at each step, it will focus on how students understand planning group activities in planning procedures, assignments, and learning objectives under the problems. Students will collaborate with their groups, be active, creative, and critical and develop soft skills.

The next step is to make observations, collect data, and analyze data related to three indicators of critical thinking, including choosing the right reasons to support the conclusions, using all appropriate information to the problem, and providing a more detailed explanation. In this step, students conclude correctly with supporting reasons and information. Students will be trained to solve problems by finding the concepts, facts, or principles integrated with one or several other scientific fields, such as science, engineering, and technology, increasing collaboration and developing critical thinking skills and creativity.

The final step, namely concluding the precise conclusions and re-checking thoroughly from start to finish. Students provide the best solutions to problems related to the concepts they have learned. It can stimulate students' critical thinking skills in the indicator of checking back thoroughly, which can be seen when students complete the steps according to their thoughts. Different from the case with students who follow expository learning. In expository learning, students tend to look indifferent in participating in learning. It is because the expository learning model is a learning model that is always used in science learning. In the expository learning model, students do not get the opportunity to do more activities than is done in the STEM-based inquiry learning model. The role of the teacher looks more dominating. Teachers convey more information to students in the same case by asking, gathering information, and communicating. In this step, only a few students actively expressed their ideas. Other students are seen just following the lesson without actively participating in contributing their ideas. Information search by students is also limited to textbooks without utilizing other learning resources.

It shows that the STEM-based inquiry learning model has an advantage over the expository learning model in improving critical thinking skills. The research results are in line with Islamyah et al. (2018) that the STEM-based guided inquiry learning model application can improve the critical thinking skills of class X MIPA 4 SMAN 2 Singaraja academic year 2018/2019. In addition, research conducted by Wariyanti (2019) also showed the inquiry learning model has a significant effect on students' critical thinking skills and learning outcomes. Maryam et al. (2021) also showed that there were differences in critical thinking skills between students in the experimental class and students in the control class ($p = 0.00 < 0.05$), so the inquiry learning model affected improving students' critical thinking skills. Based on the research results above, the STEM-based inquiry learning model is very effectively applied to improve students' critical thinking skills.

Differences in mastery of concepts between students who follow the STEM-based inquiry learning model and students who follow the expository learning model

In the experimental class, a STEM-based inquiry learning model was applied. This STEM-based inquiry learning model embodies scientific-based learning where students can discover something, encourage student learning experiences to be able to understand scientific concepts, provide a deeper understanding and make them longer memorable and meaningful for students. Science learning on a STEM-based learning model has made students active and critically able to solve problems by finding their concepts, facts, or principles that are integrated with one or several other scientific fields, such as science, engineering, and technology. The mastery score of the science concept that is greater in the experimental class than in the control class is also believed to be a result of the integrated implementation of the four aspects of STEM. The science aspect is implemented by utilizing nature as a medium/learning resource and as one of the bases for students in making decisions, whereas the technology aspects are by utilizing various current technologies in the digitalization era or the 4.0 revolution era, where technology can cause changes in life activities. Furthermore, the engineering aspect teaches procedures that students must carry out sequentially/systematically, wherein student learning is given worksheets as a guide in experimenting. Meanwhile, the mathematical aspect fosters students' reasoning in calculating and analyzing conclusions.

Meanwhile, for the expository learning model in the control class, the learning process tends to be one-way. Students only listen, take notes, and then do questions and answer. They are less invited to solve a problem that requires reasoning, so this process reduces the meaning of learning. It is because the expository learning model prioritizes memorization rather than understanding and is teacher-centered. Expository learning is not problem oriented. Students have not been trained to think critically, so students' ability to understand and solve problems has not been formed optimally, so students' mastery of science concepts is not optimal.

Differences in critical thinking ability and mastery of concepts between students who follow learning with the STEM (science, technology, engineering, and mathematics) based inquiry learning model and students who follow the expository learning model

The research results indicate that the application of the STEM (Science, Technology, Engineering, and Mathematics) based inquiry learning model is more effective for improving critical thinking skills and mastery of science concepts than the expository learning model. It is because the stages in the STEM (Science, Technology, Engineering, and Mathematics)-based inquiry learning model support and encourage the growth of the potential for increased critical thinking skills and mastery of science concepts so that these two variables can be influenced together. The inquiry learning model based on STEM (Science, Technology, Engineering, and Mathematics) provides meaningful learning and trains students' ability to solve problems by finding their concepts, facts, or principles that are integrated with one or several other scientific fields, such as science, engineering, and technology. This model also enhances collaboration, trains critical thinking skills and creativity, and provides experiences to students.

In the STEM (Science, Technology, Engineering, and Mathematics) based inquiry learning model, students are invited to develop thinking skills through specific observations to make generalizations. At that stage, students are stimulated to reason to go to the next stage. In the next stage, students are invited to formulate problems that will bring students to a problem that contains a solving puzzle. At this stage, students will interpret the things that are the subject matter. Then in the next step, students determine impermanent answers or hypotheses until they are continued by searching for various information, data, and facts needed to answer the problem/hypotheses. At this stage, they intensively develop cognitive reasoning power and knowledge to provide responsive stimulus and results under the processes carried out. After that, students test the correctness of impermanent answers, where the alleged answers are based on the obtained data. Next, students look for data or information to solve the problem either by reading learning resources, researching, asking questions, discussing, and so on. Then students analyze the data to find a concept. The next stage is students, and their groups draw conclusions and formulate rules, principles, generalization ideas, or concepts based on the data obtained.

As it is today, there is the implementation of an independent curriculum where the way to achieve learning goals is through learning strategies that provide quality learning experiences, apply a material to problems, an interactive, inspiring, fun, challenging learning atmosphere, motivate students, and develop critical thinking skills. Therefore, the inquiry learning model based on STEM (Science, Technology, Engineering, and Mathematics) becomes an alternative to achieving the expected quality of learning. Judging from the advantage factors of the STEM (Science, Technology, Engineering, and Mathematics) based inquiry learning model, it is in line with the TPACK (Technological Pedagogical Content Knowledge) model in the current IKM. The TPACK model is an integration of comprehensive knowledge and skills in terms of material and pedagogy that are integrated into technological developments and the interrelationships between content knowledge, pedagogy, and technology (Ananda et al., 2022). Teachers in this century must have Technological Pedagogical Content Knowledge (TPACK) skills, as mentioned by issues in recent learning (Ichsan et al., 2022). TPACK will make learning more effective and efficient by integrating technology (Zainuddin et al., 2022). TPACK is also an essential factor that can be used as a reference in improving the quality of learning. Therefore, TPACK (Technological Pedagogical Content Knowledge) is in line with the STEM (Science, Technology, Engineering, and Mathematics) based inquiry learning model, which both make a positive contribution to improving the quality of learning so that it will ultimately have the impact on critical thinking skills and mastery of concepts becomes better again.

Meanwhile, the expository learning model is more dominated by lecture methods and assignments. Students are not fully involved in the learning process, trained to explore and process information, trained in making the right decision or in solving a problem, and also rarely trained to carry out an investigation of a problem, formulate and determine relevant hypotheses, and collect and analyze, or students are invited to draw conclusions based on the investigation they have done. In this case, students are only recipients of information, so students' thinking skills are low, or in other words, learning is less meaningful. Therefore, students with critical thinking skills and mastery of science concepts who are taught using the STEM-based inquiry learning model are better than those with the expository learning model.

Conclusion

Based on the results of data analysis and discussion of the research results, the conclusions are 1) There are differences in critical thinking skills between students who follow the STEM-based inquiry learning model and students who follow the expository learning model; 2) There are differences in the mastery of the science concept between students who follow the STEM-based inquiry learning model and students who follow the expository learning model; 3) Simultaneously, there are differences in critical thinking skills and mastery of science concepts between students who follow the STEM-based inquiry learning model and students who follow expository learning model.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest.

References

Ananda, R., Rani, A. R., & Fadhilaturrahmi, F. (2022). Pengembangan model TPACK untuk menunjang kompetensi profesional pada guru sekolah dasar (Development of the TPACK model to support professional competence in elementary school teachers). *Jurnal Basicedu*, *6*(5), 9064-9069.

Anggareni, N. W., Ristiati, N. P., & Widiyanti, N. L. P. M. (2013). Implementasi strategi pembelajaran inkuiri terhadap kemampuan berpikir kritis dan pemahaman konsep IPA siswa SMP (Implementation of inquiry learning strategies on critical thinking skills and understanding of science concepts in junior high school students). *Jurnal Pendidikan dan Pembelajaran IPA Indonesia*, *3*(1).

Azura, A., & Octarya, Z. (2020). Desain dan uji coba buku ajar berbasis Science, Technology, Engineering and Mathematics pada materi asam basa (Design and testing textbooks based on Science, Technology, Engineering and Mathematics on acid-base materials). *JEDCHEM (Journal Education and Chemistry)*, *2*(1), 32-38.

Dahar, R. (2011). *Teori – teori belajar dan pembelajaran (Learning theories and learning).* Erlangga.

Ennis, R. H. (2015). *The Palgrave handbook of critical thinking in higher education*. The United States: Palgrave Macmillan.

Facione, P. A. (2015). Permission to reprint for non-commercial uses critical thinking: What it is and why it counts. *Insight Assessment*, *5*(1). 1-30.

Habibi, A., Sofyan, S., & Mukminin, A. (2023). Factors affecting digital technology access in vocational education. *Scientific Reports, 13*(1) doi:10.1038/s41598-023-32755-6

Habibi, A., Razak, R. A., Yusop, F. D., Muhaimin, M., Asrial, A., Mukminin, A., & Jamila, A. (2022). Exploring the factors affecting pre-service science teachers' actual use of technology during teaching practice. *South African Journal of Education, 42*(1) doi:10.15700/saje.v42n1a1955

Habibi, A., Yaakob, M.F.M., Mukminin, A., Muhaimin, M., Prasojo, L.D., Yusop, F.D. and Muzakkir, M. (2021), "Teachers' digital technology access to motivation, skills and use: a structural equation modeling study", *Aslib Journal of Information Management*, https://doi.org/10.1108/AJIM-11-2020-0382

Hidayah, R., Salimi, M., & Susiani, T. S. (2017). Critical thinking skill: Konsep dan inidikator penilaian (Critical thinking skills: Concepts and assessment indicators). *Taman Cendekia: Jurnal Pendidikan Ke-SD-an*, *1*(2), 127-133.

Hidayat, M., Putri, D. M., Fortunasari, F., Fridiyanto, F., Habibi, A., & Mukminin, A. (2021). Preparing future human resources in language learning: Efl student teachers' voices' academic stressors. *Theory and Practice in Language Studies, 11*(12), 1655-1661. doi:10.17507/tpls.1112.18

Ichsan, I., Suhaimi, S., Amalia, K. N., Santosa, T. A., & Yulianti, S. (2022). Pengaruh model pembelajaran problem based learning berbasis TPACK terhadap ketrampilan literasi sains dalam pembelajaran ipa siswa tingkat SD sampai SMA: Sebuah meta-analisis (The effect of the TPACK-based problem-based learning model on scientific literacy skills in science learning for elementary to high school students: A meta-analysis). *Jurnal Pendidikan dan Konseling (JPDK)*, *4*(5), 2173-2181.

Islamyah, D. G., Yasa, P., & Rachmawati, D. O. (2018). Penerapan model pembelajaran inkuiri terbimbing berbasis STEM guna meningkatkan kemampuan berpikir kritis siswa kelas X MIPA 4 SMAN tahun ajaran 2018/2019 (*Application of the STEM-based guided inquiry learning model to improve the critical thinking skills of class X MIPA 4 SMAN in the 2018/2019 academic year*). *Jurnal Pendidikan Fisika Undiksha*, *8*(2), 86-94.

Knaggs, C. M., & Schneider, R. M. (2012). Thinking like a scientist: Using vee-maps to understand process and concepts in science. *Research in Science Education*, *42*, 609-632.

Kodir, H. A. (2018). *Manajemen pembelajaran saintifik kurikulum 2013 pembelajaran berpusat pada siswa (Management of scientific learning curriculum 2013 student-centered learning)*. Pustaka Setia.

Kurniasih, I., & Sani, B. (2015). *Ragam pengembangan model pembelajaran untuk peningkatan profesionalitas guru (Various development of learning models to increase teacher professionalism).* Jakarta: Kata Pena.

Lestari, H., Sopandi, W., Sa'ud, U. S., Musthafa, B., Budimansyah, D., & Sukardi, R. R. (2021). The impact of online mentoring in implementing raced learning to the elementary school teachers' competence in training students' critical thinking skills: A case study during covid-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, *10*(3), 346-356.

Maknun, J. (2015). The implementation of generative learning model on physics lesson to increase mastery concepts and generic science skills of vocational students. *American Journal of Educational Research*, *3*(6), 742-748.

Maryam, A., Mohammadreza, D., Abdolhussein, S., Ghobad, R., & Javad, K. (2021). Effect of concept mapping education on critical thinking skills of medical students: A quasi-experimental study. *Ethiopian journal of health sciences*, *31*(2), 409-418.

Mirayani, P., Widana, I. W., & Purwati, N. K. R. (2021). Pengaruh model pembelajaran problem solving dan kemampuan berpikir kritis terhadap hasil belajar matematika siswa kelas XI SMA Negeri 7 Denpasar tahun pelajaran 2020/2021 (The influence of the problem solving learning model and critical thinking skills on the mathematics learning outcomes of class XI students of SMA Negeri 7 Denpasar for the 2020/2021 academic year). *Widyadari: Jurnal Pendidikan*, *22*(2), 429-438.

Mukminin, A., Habibi, A., Muhaimin, M., & Hidayat, M. (2023). Social media use for english writing (SMU-EW): Preservice english teachers. *Ampersand, 10* doi:10.1016/j.amper.2023.100112

Mukminin, A., Muhaimin, M., Prasojo, L. D., Khaeruddin, K., Habibi, A., Marzulina, L., & Harto, K. (2022). Analyzing social media use in tefl via the technology acceptance model in indonesian higher education during the covid-19 pandemic. *Teaching English with Technology,* (1), 3-22.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press.

Rakimahwati, Ismet, S., Zainul, R., Roza, D., & Mukminin, A. (2022). The development of the educational game to improve logical/ mathematical intelligence. *Journal of Higher Education Theory and Practice, 22*(7), 11-19. doi:10.33423/jhetp.v22i7.5266

Sandi, G. (2021). Pengaruh pendekatan STEM untuk meningkatkan pemahaman konsep elektroplating, keterampilan berpikir kritis dan bekerja sama (The influence of the STEM approach to improve understanding of electroplating concepts, critical thinking and teamwork skills). *Indonesian Journal of Educational Development*, *1*(4), 579-585.

Sofwan, M., Pratama, R., Muhaimin,M., Yusnaidar,Y., Mukminin, A., & Habibi, A.(2021).Contribution of technology innovation acceptance and organizational innovation climate on innovative teaching behavior with ICT in indonesian education. *Qwerty, 16*(1), 33-57

Soros, P., Ponkham, K., & Ekkapim, S. (2018). The results of STEM education methods for enhancing critical thinking and problem solving skill in physics the 10th grade level. In *AIP Conference Proceedings*, *1923*(1), 30-45.

Susanti, N., Hadiyanto, & Mukminin, A. (2022). The effects of TPACK instrument variables on teacher candidates in higher education. *Journal of Higher Education Theory and Practice, 22*(2), 107-115. doi:10.33423/jhetp.v22i2.5041

Susmariani, N. K., Widana, I. W., & Adi, I. N. R. (2022). Pengaruh model pembelajaran inkuiri terbimbing berbasis blended learning dan kemandirian belajar terhadap hasil belajar matematika siswa sekolah dasar (The influence of the guided inquiry learning model based on blended learning and learning independence on the mathematics learning outcomes of elementary school students). *Jurnal Ilmiah Pendidikan Citra Bakti*, *9*(1), 230-239.

Tohir, M. (2019). *Indonesia's PISA results in 2018 are lower than 2015*. Tailable.

Velasco, E. V., Ibarra, F. P., & Mukminin, A. (2022). The readiness on the implementation of the special program for information and communication technology. *Journal of Higher Education Theory and Practice, 22*(3), 79-89. doi:10.33423/jhetp.v22i3.5083

Wariyanti, A. (2019). Pengaruh model pembelajaran inkuiri terhadap kemampuan berpikir kritis dan hasil belajar siswa kelas IV SD pada subtema Keindahan Alam Negeriku (The effect of the inquiry learning model on critical thinking skills and learning outcomes of fourth-grade elementary school students on the sub-theme *Keindahan Alam Negeriku*). *Jurnal Review Pendidikan Dasar: Jurnal Kajian Pendidikan dan Hasil Penelitian*, *5*(2), 1019-1024.

Wibawa, I. P. G. S. T. (2020). Pengaruh model pembelajaran inkuiri berbasis stem dengan penugasan berbantuan aplikasi Whatsapp terhadap partisipasi orang tua dan hasil belajar IPA siswa kelas IV SD Se-Gugus VIII Mengwi (The effect of the stem-based inquiry learning model with assignments assisted by the Whatsapp application on parental participation and science learning outcomes for fourth-grade students of Elementary schools in Gugus VIII Mengwi). *Pendasi: Jurnal Pendidikan Dasar Indonesia*, *4*(2), 79-90.

Widana, I. W., & Muliani, L. P. (2020). *Uji persyaratan analisis (Test requirements analysis)*. Klik Media.

Widana, I. W., Sopandi, A. T., & Suwardika, G. (2021). Development of an authentic assessment model in mathematics learning: A science, technology, engineering, and mathematics (STEM) approach. *Indonesian Research Journal in Education| IRJE*, 5(1), 192-209.

Zainuddin, M., Saifudin, A., Lestariningsih, L., & Nahdiyah, U. (2022). Pengembangan Big Book dengan model TPACK dalam meningkatkan kemampuan literasi menulis anak SD (Development of Big Book with the TPACK model in improving elementary school children's writing literacy skills). *Briliant: Jurnal Riset dan Konseptual*, *7*(3), 770-777.

Biographical Notes

NI PUTU EVI YUPANI, S.Pd. SD., was born in Jembrana, April 2, 1991. Previously served as a teacher at SDN 2 Tegal Badeng (2013-2014), SDN 1 Pengambengan (2014-2015), SDN 3 Pujungan (2015-present). Completed bachelor degree at Ganesha University of Education (2009-2013). Has a hobby of dancing and singing, and is fluent in Indonesian and English. Participated in various education and training programs, including: Learning Competency Improvement Program (2019), INDONESIA TEACHING FELLOWSHIP Teacher Training Program (2020), Teacher's Strategic Role in the 2013 Curriculum and the Era of the Industrial Revolution 4.0 in the 21st Century in Preparing the Golden Generation in 2045 (2020), Building Verse-Long Learners (2020), Designing Learning Media Using Kahoot (2021), Designing Learning Media Using Quizz (2022), Bipolar Disorder Webinar Series (2022), The Use of Quizz in the Implementation of the Independent Curriculum (2023), Training on Making Teaching Materials for the Merdeka Teaching Platform (2023).

Dr. I WAYAN WIDANA, S.Pd., M.Pd., is a lecturer at PGRI Mahadewa Indonesia University. Has studied bachelor degree in Mathematics Education at the Open University, Masters in Educational Research and Evaluation at the Ganesha University of Education, and Doctoral Degree in Educational Research and Evaluation at Jakarta State University. Areas of expertise in education measurement and evaluation. Currently assigned as Chair of the Research and Community Service Learning Institute. As an expert trainer at the driving school (*Sekolah Penggerak*) of the Ministry of Education, Culture, Research and Technology.