RESEARCH ARTICLE

Analysis of innovative and inquiry biology learning design in in-service teacher students

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Abstract: The implementation of the Kurikulum Merdeka strongly recommends a model based on inquiry or investigations carried out actively by students. This study was conducted to analyze the tendencies of permanent teacher students in developing inquiry-based learning and its correlation with students' critical thinking skills. This survey research uses students of the biology in-service teacher at the University of Muhammadiyah Malang as a sample. The variables measured in this research include the variety of methods used, the variety of ways of perceiving problems, student collaboration activities, and the learning instructional quality. Data collection uses survey instruments that have been validated and reliable. Instrument validation uses the product moment validity test, while the reliability test uses the Alpha-Cronbach's formula. The data obtained were analyzed using the Spearman's Rho correlation formula. The research results showed that the methods most frequently applied were group discussions (90.08%), presentations (82.64%), and questions and answers (76.86%). The most common way of apperception is by asking about experiences (70.25%) and stimulating students to share experiences (33.38%). Furthermore, teachers also provide collaboration space in most learning activities amounting to 67.77%. However, most new students disseminated definitions of terms in the project (64.46%) rather than explaining how the project was carried out (52.89%). Furthermore, the student worksheets developed have dominant problem solving activities (84.30%), have relevance to the learning model (72.73%), and evaluation questions have led to HOTS optimization. The research results also show a strong positive correlation (ρ=0.431, p<0.001) which shows that the relevance of student worksheets is strongly related to student HOTS.

Keywords: innovative learning design; inquiry-based; in-service teacher

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Introduction

The results of the 2022 PISA survey, which was carried out after the pandemic, clearly indicate the challenges facing the world of education globally (OECD, 2023a, 2023b). These results are actually in line with the predictions of several researchers who said that there would be a decline in the quality of learning as a result of school closures and online learning during the pandemic period (Demircioglu et al., 2022; Engzell et al., 2021; Lafifa et al., 2022). More specifically, Indonesian students' scores in mathematics, reading, and science have decreased by around 12 – 13 points from 2018 (Schleicher, 2023). Although this downward trend in scores occurs in almost all countries, these results certainly imply the extra efforts needed to discover by education stakeholders in Indonesia to uplifting the quality

of learning (Kim et al., 2019; Pang, 2022).
Improving the quality of learning in schools is indicated as one of the key factors that can improve the quality of education in Indonesia (Jovanka et al., 2021; Permanasari, 2016; Rajendra & Sudana, 2018). In general, the implementation of an independent curriculum (*Kurikulum Merdeka*) is an interpretation of steps to improve the quality of learning (Indarta et al., 2022; Suriswo et al., 2023) that is adapted to the context and local wisdom (Sumartias et al., 2020) that applies in each school. Therefore, the government actively continues to socialize policies and expand the scope of implementation of the independent curriculum at every level of education (Hasanah et al., 2022).
In its implementation, the curriculum places great emphasis on implementing learning that optimizes 21st-century skills such as critical thinking skills, creative thinking, communication, and collaboration through innovative learning models (Indarta et al., 2022). Furthermore, the learning model that is highly recommended is a model that is based on inquiry or investigations carried out actively by students (Gunawan et al., 2020; Ješková et al., 2022; Kambeyo & Csapo, 2018). More specifically, the inquiry models that are widely recommended by researchers are problem-based learning (PBL) (Casanoves et al., 2017; Pluta et al., 2013) and project-based learning (PjBL) (Ilma et al., 2022; Zhou, 2021).
However, on the other hand, strengthening teacher competence is also a fundamental thing to do to ensure that the mission of improving the quality of learning can be achieved (Indarta et al., 2022; Le et al., 2018). Competency strengthening includes provision in programs such as driving teachers and driving schools, as well as through academic programs such as professional teacher education, both pre-service and in-service (Patilima, 2022; Syafi'i, 2021). In reality, many teachers, in this case in-service teacher students, encounter difficulties in actualizing inquiry-based innovative learning in teaching modules and their implementation (Cahyaningtyas et al., 2020; Pattimura et al., 2020).
Some of the obstacles that are often faced are how to choose contextual problems and perceive them to students (Hendri et al., 2021; Nareswari et al., 2021). Several researchers state that the main component of inquiry-based learning is the availability of contextual problems that students need to solve in the learning process (Kennedy & Odell, 2014; Teo et al., 2021). In addition, teachers are sometimes faced with limitations in the relevant method options to use or limitations in increasing the level of existing options. The obstacles encountered during the planning period are indicated to have implications for how the learning and evaluation process occurs (Lee & Takahashi, 2011; Orosz et al., 2022).
Research on how student teachers work in this position can provide an overview of the extent to which they think in planning innovative learning. One of the positive impacts that can be taken from this research is that it illustrates the options for innovation in learning that can be developed. This research was conducted to analyze the tendencies of professional students in positions to design innovative, inquiry-based learning and how it correlates to students' critical thinking.

Method

This survey-correlational research was conducted from October 2023 to February 2024. The research subject in this research was biology in-service teacher students in the Department of Teacher Professional Education at the University of Muhammadiyah Malang. Furthermore, those subjects are from Junior High Schools (JHS) and Senior High Schools (SHS) in any region of Indonesia
The primary data is video either in the first or second phase of the field internship teaching program. As many as 121 videos were analyzed during this research conducted. All the learning videos have been accessed through the learning management system (LMS) made by The Ministry of Education, Culture, Research and Technology, Republic of Indonesia.

Table 1. Research variables

No	Variables	Components
1	Learning Model	a) Project-based
		b) Problem-based
2	Variety of Methods	a) Discourse
		b) Group discussion
		c) Hands-on
		d) Demonstration
		e) Q & A
		f) Literature review
		g) Observation
		h) Presentation
		i) Tasks
3	Apperception and Problem Orienting	a) Way to apperception
		b) Type of question
		c) Apperception technique

No	Variables	Components
		d) Media in providing apperception
		e) Way to orienting problem
		f) Completeness of the inquiry line of thinking
4	Space for collaboration and reflection	a) Students' collaboration
		b) Results dissemination
		c) Space for students' reflection
5	Quality of the learning instructional	a) Content of students' worksheet
		b) Format of students' worksheet
		c) Learning material
		d) Relevance of evaluation questions
		e) HOTS questioning level

To obtain data, the researchers use valid and reliable instruments. Instruments validity testing uses product-moment, while the reliability test uses Alpha-Cronbach's. The measured variable in this research, mentioned in Table 1, consists of five variables i.e. learning model, variety of methods, apperception and problem orienting, space for collaboration and reflection, and quality of the learning instructional. The correlation among the variables was measured using Spearman's Rho formula after converting data to an ordinal scale (Kazhikenova et al., 2021).

Results and Discussion

A total of 121 learning videos have been successfully analyzed in this research. Figure 1 shows that the majority of subjects in this study were SHS teachers with a percentage of 95.04%, while a small portion (4.96%) were JHS. Furthermore, the learning videos analyzed in this study were mostly at the SHS level, namely at class 10 and 11 with percentages of 44.63% and 41.32% respectively, while class 12 had a representation of 9.09%. Only a small portion of the subjects we studied took lessons at the JHS level, namely the 7th, 8th, and 9th grades, which had very small representation. Meanwhile, the learning model that is most widely used is PjBL (51.24%), slightly more dominant than PBL with a percentage of 48.76%.

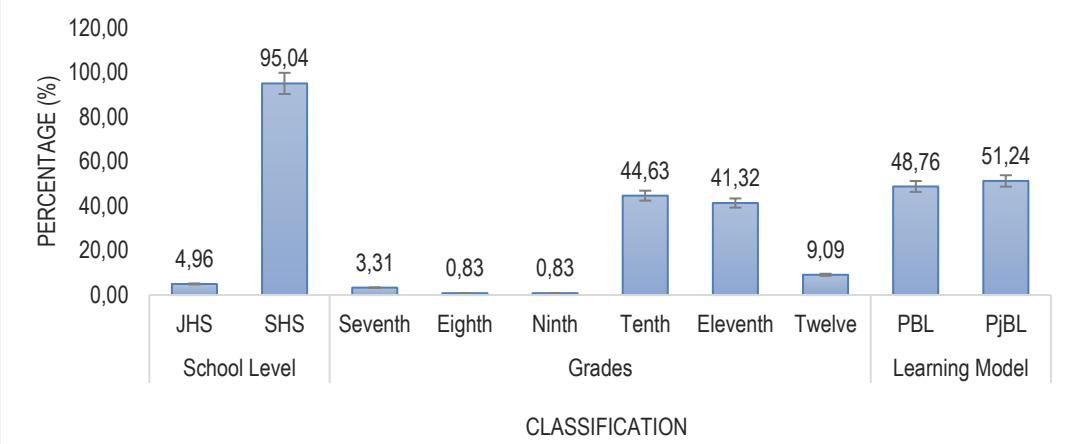

Figure 1. Kinds of methods used by the teachers during learning process

The implementation of these two learning models certainly cannot be separated from the methods used integrally. Some of the most frequently applied methods, in this study, were group discussions (90.08%), followed by presentations (82.64%), and lectures (60.33%). Questions and answers are also another frequently used option with a percentage of 76.86%. These four methods are considered very familiar to teachers because they have a fairly high percentage above 60%.

There are several reasons why these three methods are often chosen by teachers in planning inquiry learning. The first reason is that the project method tends to be designed for group learning (Davidsen et al., 2020; Raymundo, 2020). This means that it is rather difficult or tends to be forced if project learning is carried out individually unless it is carried out as a variation in group activities (Burgess et al., 2018). For instance, carry out an analysis individually before discussing it in a large group. Another reason is that teachers need to measure readiness and monitor the learning process of student groups through a series of questions, whether structured or not. These questions and answers are intended to stimulate students' thinking skills (Selvaretnam, 2024; Yi et al., 2021). Another reason is that the presentation method is needed to give students space to convey the results of discussions and test the results of their

thinking within the class community (Li et al., 2020; Utomo et al., 2020).
Several other methods such as practicum (17.36%), observation (22.31%), and reviewing literature (10.74%) have lower percentages. Demonstration, mastery, and other methods have the lowest percentages, respectively 9.09%, 4.13%, and 9.92%. It is important to note that the total percentage of all methods in Figure 2 is more than 100%. This shows that in one learning session, teachers can apply more than one method. Therefore, this research provides a rich picture of the variety of learning methods used by teachers in practice.

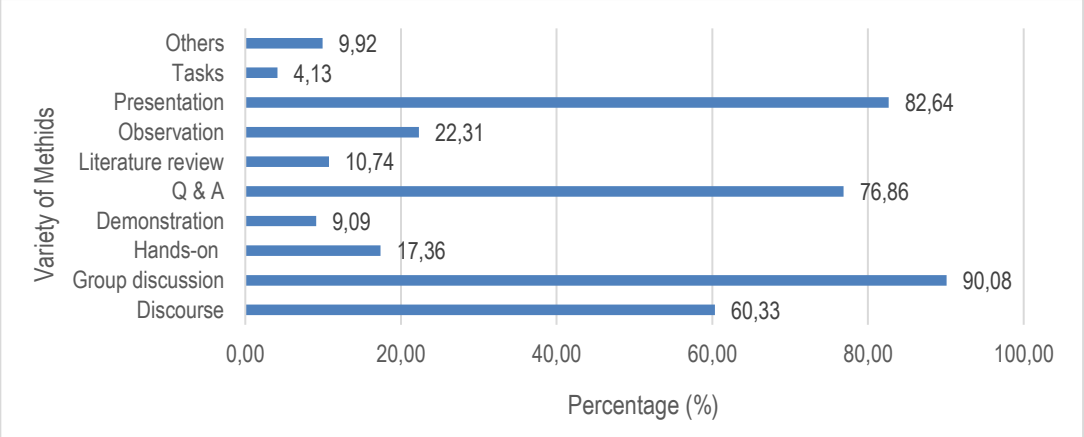

Figure 2. Kinds of methods used by the teachers during learning process

According to several researchers, the method of apperception is an important factor in emphasizing how important it is for a problem to be resolved (Eslahchi, 2023; Lelinge, 2023). In this case, teachers have a key role in linking contextual problems around students with learning through appropriate apperception (Mohammad & Kamran, 2023; Shore & Dinning, 2023). We tried to consider teachers' tendencies in conducting apperception. The research results, in Table 2, show that there are various ways of apperception, apperception techniques, and ways of identifying and solving problems applied by teachers in the videos analyzed.

Table 2. How the teachers make an apperception

Variable	n	Percentage
Way to apperception		
Asking about the previous material	66	54.55%
Asking about students' relevance experiences	85	70.25%
Explaining previous material	19	15.70%
Explaining the upcoming material	10	8.26%
Not defined	4	3.31%
Type of question		
Definitional question	29	23.97%
Experiential question	48	39.67%
Stimulating students to sharing	41	33.88%
Not defined	3	2.48%
Apperception technique		
Classical, from the beginning to the end	57	47.11%
Classical, combine with personal interaction	78	64.46%
Personal, from the beginning to the end	19	15.70%
Not defined	3	2.48%
Media in providing apperception		
Using multimedia (video, audio, and graph)	93	76.86%
Using data	23	19.01%
Using text	57	47.11%
Not defined	2	1.65%
Way to orienting problem		
Problems related to to students	88	72.73%
Problems not related to students	36	29.75%
There is problem, but not contextual to the students	13	10.74%
There are no obvious problems	24	19.83%

There are two things that teachers do most when perceiving learning, the first is asking about previous lesson material. The percentage for this method is quite high at 54.55%. However, interestingly, many teachers have also been able to link students' experiences related to the material to be studied. This method is done more often with a percentage of 70.25%. As previously explained, teachers can apply these methods individually or in combination with both. The percentage of these two methods is much higher than the apperception method by explaining concepts, either in the previous material or the material to be studied. Furthermore, in relating the material to students' experiences, quite a lot of teachers stimulate students to share personal experiences related to the material to be taught. The percentage of apperception questions of this kind that are also used quite frequently is 33.88%. In this case, the teacher is quite active in asking more in-depth questions regarding students' experiences so that they can find out more precisely what the student's initial knowledge and readiness for learning are (Frolova et al., 2021; Shore & Dinning, 2023). In other words, the teacher not only asks about students' experiences but goes further than that by actively stimulating students to share (Fleischner et al., 2017; Sellars et al., 2018).

Table 2 also figures out another perspective on how apperception takes place in a classroom. The apperception technique most often used by teachers is classical with a variation of personal interaction (64.46%). This technique allows teachers to act flexibly to explore students' prior knowledge. It is done to get deeper attention and bonding from students. Other techniques such as classical without variations and personal apperception from beginning to end (47.11%), only in initial activities (15.70%), or other techniques, are not used often enough. In orienting the students to contextual problems, teachers used multimedia, such as video, audio, and images. This percentage is relatively high at 76.86%, apart from using text (47.11%), and data or infographics (19.01%). Interestingly, in selecting problems, as many as 72.73% of teachers could choose problems that were contextually close to students. This shows how teachers bridge students' learning with their daily lives.

On the other hand, the quality of student worksheets, teaching materials, and evaluation instruments is also a consideration for teachers in designing innovative and inquiry-based learning (Table 3). As many as 84.30% of student worksheets contain a collection of problem-solving activities or projects, while 15.70% only contain a collection of questions. Furthermore, in terms of student worksheet formats, 72.73% are relevant to the learning model and 27.27% are not relevant. Teaching materials containing important concepts relevant to the project or problem reached 66.12%, while those that were not relevant reached 33.88%. Regarding the relevance of evaluation questions, almost all of them were relevant to the learning experience, whether overall (47.93%) or mostly relevant (46.28%). From this data, it can be concluded that this research involves various aspects of the quality of student worksheets, teaching materials, and evaluation instruments produced by teachers in practice. However, some aspects are more dominant than others.

Table 3. How the teachers designing the instructional media

Variable	n	Percentage
Content of Students' Worksheet		
Containing problem-solving steps	102	84.30%
Containing set of questions	19	15.70%
Format of students' worksheet		
Relevant with learning model	88	72.73%
Irrelevant	33	27.27%
Learning material		
Contextual, relating to the project	80	66.12%
Textual context, not relating to the project	41	33.88%
Relevance of evaluation questions		
Relevant	58	47.93%
Most of it relevant	56	46.28%
Some are relevant	7	5.79%
HOTS questioning level		
All questions are HOTS	54	44.63%
Mostly HOTS	44	36.36%
Some are HOTS	23	19.01%

Several researchers state that the success of inquiry learning is largely determined by the learning instructional used and the teacher's ability to organize the learning flow (Dvir et al., 2023; Sari et al., 2022). Well-defined learning objectives are important in guiding students in the inquiry process (Aiman et al., 2020; Kuhn, 2015). On the other hand, it also makes teachers easier to design learning experiences and guide students (Orosz et al., 2022). Therefore, teachers need to detail the scientific steps that students need to take in investigating and solving the problems given. Variations in inquiry learning concern teachers in designing, one of the reasons is paying attention to students' prior knowledge (Oğuz-Ünver & Arabacioğlu, 2011; Ylostalo, 2020), age (Thuneberg et al., 2018), and the availability of relevant learning resources (Tuamsuk, 2013). For instance, in implementing guided inquiry, teachers need to ensure there is sufficient guidance to navigate the student inquiry process (Karunanayaka et al., 2016).

In implementing innovative and inquiry-based learning, we also pay attention to student collaboration spaces (Dvir et al., 2023; Koh et al., 2010). Table 4 shows that there are various collaboration and reflection activities implemented in the learning video recordings. Most teachers have facilitated collaboration in most learning activities (67.77%). Several other percentages also show that teachers provide space for collaboration in all learning activities (29.75%). Only a small number of learning activities (2.48%) provide very little space for collaboration. These results indicate that no learning activity provides space for students to collaborate. How do students disseminate the results of collaboration? The research results showed that most students (64.46%) explained the definitions of terms in the project. Several students (59.89%) explained how the project was carried out. Some students expressed reasons for selecting the project (16.53%), highlighted interesting things in the project (32.23%), and others (4.13%). At the end of the lesson, most students (86.78%) were given space for reflection by the teacher.

Table 4. How students collaborate and disseminate

Variable	n	Percentage
Students' collaboration		
Almost in all learning activities	36	29.75%
In most learning activities	82	67.77%
Inadequate	3	2.48%
None	0	0.00%
Results dissemination		
Explaining the definition related to the project	78	64.46%
Explaining how the projects had work	64	52.89%
Explaining the reasons behind the project	20	16.53%
Highlighting some interesting thing during the project	39	32.23%
Others	5	4.13%
Students' reflection		
Exist	105	86.78%
None	16	13.22%

To measure the correlation between several variables that we studied, we converted the nominal scale to ordinal for analysis using Spearman's rho (Table 5). The results of Spearman's Rho correlation analysis show several significant relationships between variables. There is a strong positive correlation between the relevance of student worksheets and HOTS evaluations ($\rho=0.431$, $p<0.001$), which shows that the relevance of student worksheets is strongly related to the evaluation of higher-order thinking skills (HOTS). Likewise, the relevance of evaluation questions also showed a significant correlation with HOTS evaluation ($\rho=0.261$, $p<0.01$), indicating that the relevance of evaluation questions contributed to HOTS evaluation. However, there was a weaker but still significant correlation between the relevance of teaching materials and the relevance of evaluation questions ($\rho=0.260$, $p<0.01$). This data shows that all these factors are interconnected, but the relevance of the student worksheet plays an important role in evaluating HOTS.

Table 5. The correlation among variables

Variable		Content of students' worksheet	Students' worksheet relevance	Learning material relevance	Evaluation question relevance	HOTS relevance
Content of students' worksheet	Spearman's rho	—				
	p-value	—				
Students' worksheet relevance	Spearman's rho	0.399***	—			
	p-value	< .001	—			
Learning material relevance	Spearman's rho	0.075	0.307***	—		
	p-value	0.414	< .001	—		
Evaluation question relevance	Spearman's rho	0.002	0.427***	0.260**	—	
	p-value	0.981	< .001	0.004	—	
HOTS relevance	Spearman's rho	0.073	0.431***	0.261**	0.597***	—
	p-value	0.428	< .001	0.004	< .001	—

These results show that well-planned and systematic inquiry learning innovations in learning instructional have an impact on learning outcomes (Peffer et al., 2015; Sari et al., 2022). This not only refers to short-term goals in the learning, but also to the larger impact on students' critical thinking skills (Febri et al., 2020; Syahrial et al., 2019). Researchers believe that changes in thinking skills are not achieved incidentally but from innovation after innovation carried out gradually and consistently (Syafii & Yasin, 2013). In this case, the in-service teacher students have been able to lay down and take good initial steps to ensure the continuity of learning.

Conclusion

The research results show that in-service teacher students have been able to design and implement inquiry-based learning innovations with relevant apperception and varied techniques. Furthermore, teachers have also been able to create instructional media such as student worksheets relevant to the chosen learning model, as well as integrate learning experiences and evaluations that stimulate critical thinking skills. The research results show a strong relationship between student worksheets and the evaluation of critical thinking skills.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

F. J. Miharja: writing original draft preparation, **A. Fauzi:** methodology and analysis; **L. Zaine** and **F. D. Prabandari:** integrating data.

References

Aiman, U., Hasyda, S., & Uslan. (2020). The influence of process oriented guided inquiry learning (POGIL) model assisted by realia media to improve scientific literacy and critical thinking skill of primary school students. *European Journal of Educational Research*, *9*(4), 1635–1647. https://doi.org/10.12973/EU-JER.9.4.1635

Burgess, A., Roberts, C., Ayton, T., & Mellis, C. (2018). Implementation of modified team-based learning within a problem based learning medical curriculum: A focus group study. *BMC Medical Education*, *18*(1), 1–7. https://doi.org/10.1186/s12909-018-1172-8

Cahyaningtyas, A. P., Sari, Y., Yustiana, S., & Jupriyanto, J. (2020). Pelatihan penyusunan soal-soal berbasis HOTS dan aplikasinya dalam pembelajaran daring di sekolah dasar. *Indonesian Journal of Community Services*, *2*(2), 162. https://doi.org/10.30659/ijocs.2.2.162-171

Casanoves, M., Salvadó, Z., González, Á., Valls, C., & Novo, M. T. (2017). Learning genetics through a scientific inquiry game. *Journal of Biological Education*, *51*(2), 99–106. https://doi.org/10.1080/00219266.2016.1177569

Davidsen, J., Ryberg, T., & Bernhard, J. (2020). "Everything comes together": Students' collaborative development of a professional dialogic practice in architecture and design education. *Thinking Skills and Creativity*, *37*(June), 100678. https://doi.org/10.1016/j.tsc.2020.100678

Demircioglu, T., Karakus, M., & Ucar, S. (2022). Developing students' critical thinking skills and argumentation abilities through augmented reality-based argumentation activities in science classes. *Science & Education*, *32*, 1–31. https://doi.org/10.1007/s11191-022-00369-5

Dvir, B., Rutten, L., Butville, D., & Wilson, E. (2023). Partnering to support K-12 instruction of difficult topics through inquiry-based professional learning. *School-University Partnerships*, *16*(2), 101–109. https://doi.org/10.1108/sup-03-2023-0017

Engzell, P., Frey, A., & Verhagen, M. D. (2021). Learning loss due to school closures during the COVID-19 pandemic. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(17). https://doi.org/10.1073/PNAS.2022376118

Eslahchi, M. (2023). Leadership and collective learning: a case study of a social entrepreneurial organisation in Sweden. *Learning Organization*, *30*(6), 815–833. https://doi.org/10.1108/TLO-11-2022-0133

Febri, A., Sajidan, S., Sarwanto, S., & Harjunowibowo, D. (2020). Guided Inquiry Lab: Its Effect to Improve Student's Critical Thinking on Mechanics. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *9*(1), 87–97. https://doi.org/10.24042/jipfalbiruni.v9i1.4630

Fleischner, T. L., Espinoza, R. E., Gerrish, G. A., Greene, H. W., Kimmerer, R. W., Lacey, E. A., Pace, S., Parrish, J. K., Swain, H. M., Trombulak, S. C., Weisberg, S., Winkler, D. W., & Zander, L. (2017). Teaching biology in the field: Importance, challenges, and solutions. *BioScience*, *67*(6), 558–567. https://doi.org/10.1093/biosci/bix036

Frolova, E. V., Rogach, O. V., Tyurikov, A. G., & Razov, P. V. (2021). Online student education in a pandemic: New challenges and risks. *European Journal of Contemporary Education*, *10*(1), 43–52. https://doi.org/10.13187/ejced.2021.1.43

Gunawan, G., Harjono, A., Nisyah, M., Kusdiastuti, M., & Herayanti, L. (2020). Improving students' problem-solving skills using inquiry learning model combined with advance organizer. *International Journal of Instruction*, *13*(4), 427–442. https://doi.org/10.29333/iji.2020.13427a

Hasanah, N., Sembiring, M., Afni, K., Dina, R., & Wirevenska, I. (2022). Sosialisasi kurikulum merdeka merdeka belajar untuk meningkatkan pengetahuan para guru di SD Swasta Muhamaddiyah 04 Binjai. *Ruang Cendikia : Jurnal Pengabdian Kepada Masyarakat*, *1*(3), 235–238. https://jurnal.arkainstitute.co.id/index.php/ruang-cendekia/article/view/339

Hendri, S., Handika, R., Kenedi, A. K., & Ramadhani, D. (2021). Pengembangan modul digital pembelajaran matematika berbasis science, technology, engineering, mathematic untuk calon guru sekolah dasar. *Jurnal Basicedu*, *5*(3), 1252–1258. https://doi.org/10.31004/basicedu.v5i4.1172

Ilma, S., Henie, M., Al-Muhdhar, I., Rohman, F., & Sari, M. S. (2022). Promoting students' metacognitive awareness and cognitive learning outcomes in science education. *International Journal of Evaluation and Research in Education (IJERE)*, *11*(1), 20–30. https://doi.org/10.11591/ijere.v11i1.22083

Indarta, Y., Jalinus, N., Waskito, W., Samala, A. D., Riyanda, A. R., & Adi, N. H. (2022). Relevansi kurikulum merdeka belajar dengan model pembelajaran abad 21 dalam perkembangan era society 5.0. *Edukatif : Jurnal Ilmu Pendidikan*, *4*(2), 3011–3024. https://doi.org/10.31004/edukatif.v4i2.2589

Ješková, Z., Lukáč, S., Šnajder, Ľ., Guniš, J., Klein, D., & Kireš, M. (2022). Active Learning in STEM Education with Regard to the Development of Inquiry Skills. *Education Sciences*, *12*(10). https://doi.org/10.3390/educsci12100686

Jovanka, D. R., Sumantri, M. S., Dhieni, N., & Karnadi. (2021). Early Childhood Educators' Attitude toward STEAM and Online Learning as 21-st Century Skills. *Indonesian Journal of Early Childhood Education Studies*, *10*(2), 128–135. https://doi.org/10.15294/ijeces.v10i2.47862

Kambeyo, L., & Csapo, B. (2018). Scientific reasoning skills: A theoretical background on science education. *Reform Forum*, *26*(1), 27–36. https://www.researchgate.net/publication/329196813_scientific_reasoning_skills_a_theoretical_background_on_science_education

Karunanayaka, S. P., Rajendra, J. C. N., Ratnayake, H. U. W., & Naidu, S. (2016). Peer-facilitated discussions to enhance OER-based e-learning. *Asian Association of Open Universities Journal*,

11(1), 90–104. https://doi.org/10.1108/AAOUJ-07-2016-0022
Kazhikenova, G., Zhumataeva, E., Kozhamzharova, M., & Aubakirova, S. (2021). The effectiveness of reflective dialogue in the development of reflective thinking in rising teachers. *Thinking Skills and Creativity*, *41*(July). https://doi.org/10.1016/j.tsc.2021.100902
Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258. https://eric.ed.gov/?id=EJ1044508
Kim, S., Raza, M., & Seidman, E. (2019). Improving 21st-century teaching skills: The key to effective 21st-century learners. *Research in Comparative and International Education*, *14*(1), 99–117. https://doi.org/10.1177/1745499919829214
Koh, J. H. L., Herring, S. C., & Hew, K. F. (2010). Project-based learning and student knowledge construction during asynchronous online discussion. *Internet and Higher Education*, *13*(4), 284–291. https://doi.org/10.1016/j.iheduc.2010.09.003
Kuhn, D. (2015). Thinking together and alone. *Educational Researcher*, *44*(1), 46–53. https://doi.org/10.3102/0013189X15569530
Lafifa, F., Parno, P., Hamimi, E., & Setiawan, A. M. (2022). Development of STEM animation learning media with feedback to facilitate students' critical thinking ability on global warming materials. *Proceedings of the Eighth Southeast Asia Design Research (SEA-DR) & the Second Science, Technology, Education, Arts, Culture, and Humanity (STEACH) International Conference (SEADR-STEACH 2021)*, *627*, 8–15. https://doi.org/10.2991/assehr.k.211229.002
Le, H., Janssen, J., & Wubbels, T. (2018). Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration. *Cambridge Journal of Education*, *48*(1), 103–122. https://doi.org/10.1080/0305764X.2016.1259389
Lee, Y. A., & Takahashi, A. (2011). Lesson Plans and the Contingency of Classroom Interactions. *Human Studies*, *34*, 209–227. https://doi.org/10.1007/s10746-011-9181-1
Lelinge, B. (2023). Predicting challenges to student learning in a learning study: Analysing the intended object of learning. *International Journal for Lesson and Learning Studies*, *12*(2), 126–138. https://doi.org/10.1108/IJLLS-03-2022-0032
Li, B., Jia, X., Chi, Y., Liu, X., & Jia, B. (2020). Project-based learning in a collaborative group can enhance student skill and ability in the biochemical laboratory: a case study. *Journal of Biological Education*, *54*(4), 404–418. https://doi.org/10.1080/00219266.2019.1600570
Mohammad, R. F., & Kamran, M. (2023). Examining the efficacy of online learning in nurturing students' learning: an analysis of students' experiences. *Asian Association of Open Universities Journal*, *18*(3), 218–232. https://doi.org/10.1108/AAOUJ-11-2022-0163
Nareswari, N. L. P. S. R., Suarjana, I. M., & Sumantri, M. (2021). Belajar Matematika dengan LKPD Berbasis Kontekstual. *Mimbar Ilmu*, *26*(2), 204. https://doi.org/10.23887/mi.v26i2.35691
OECD, O. (2023a). PISA 2022 Results (Volume I): The state of learning and equity in education. In *PISA: Vol. I*. https://doi.org/10.31244/9783830998488
OECD, O. (2023b). PISA 2022 Results (Volume II): Learning During – and From – Disruption. In *OECD Publishing: Vol. II*. https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-ii_a97db61c-en
Oğuz-Ünver, A., & Arabacioğlu, S. (2011). Overviews on inquiry based and problem based learning methods. *Western Anatolia Journal of Educational Sciences (WAJES)*, *Selected papers presented at WCNTSE*, 303–310. http://webb.deu.edu.tr/baed/giris/baed/ozel_sayi/303-310.pdf
Orosz, G., Németh, V., Kovács, L., Somogyi, Z., & Korom, E. (2022). Guided inquiry-based learning in secondary-school chemistry classes: a case study. *Chemistry Education Research and Practice*, *24*(1), 50–70. https://doi.org/10.1039/d2rp00110a
Pang, N. S. K. (2022). Teachers' reflective practices in implementing assessment for learning skills in classroom teaching. *ECNU Review of Education*, *5*(3), 470–490. https://doi.org/10.1177/2096531120936290
Patilima, S. (2022). Sekolah penggerak sebagai upaya peningkatan kualitas pendidikan. *Prosiding Seminar Nasional Pendidikan Dasar*, *0*(0), 228–236. http://ejurnal.pps.ung.ac.id/index.php/PSNPD/article/view/1069
Pattimura, S. ., Maimunah, M., & Hutapea, N. M. (2020). Pengembangan perangkat pembelajaran matematika menggunakan pembelajaran berbasis masalah untuk memfasilitasi pemahaman matematis peserta didik. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *4*(2), 800–812. https://doi.org/10.31004/cendekia.v4i2.286
Peffer, M. E., Beckler, M. L., Schunn, C., Renken, M., & Revak, A. (2015). Science Classroom Inquiry (SCI) simulations: A novel method to scaffold science learning. *PLoS ONE*, *10*(3), 1–14. https://doi.org/10.1371/journal.pone.0120638
Permanasari, A. (2016). STEM education: Inovasi dalam pembelajaran sains. *Prosiding Seminar Nasional Pendidikan Sains*, 23-. https://jurnal.fkip.uns.ac.id/index.php/snps/article/view/9810
Pluta, W. J., Richards, B. F., & Mutnick, A. (2013). PBL and Beyond: Trends in collaborative learning. *Teaching and Learning in Medicine*, *25*(SUPPL.1). https://doi.org/10.1080/10401334.2013.842917

Rajendra, M. I., & Sudana, M. I. (2018). The influence of interactive multimedia technology to enhance achievement students on practice skills in mechanical technology. *Journal of Physics: Conference Series*, *953*(012104), 0–5. https://doi.org/10.1088/1742-6596/953/1/012104

Raymundo, M. R. D. R. (2020). Fostering creativity through online creative collaborative group projects. *Asian Association of Open Universities Journal*, *15*(1), 97–113. https://doi.org/10.1108/AAOUJ-10-2019-0048

Sari, R. S., Ningsi, N., Nasarudin, N., & Hakim, A. R. (2022). Free inquiry learning model with experimental methods on the learning outcomes of class X students of senior high school on the subject of motion. *Jurnal Pendidikan Fisika Indonesia*, *18*(2), 165–173. https://doi.org/10.15294/jpfi.v18i2.28083

Schleicher, A. (2023). PISA 2022: Insights and Interpretations. In *OECD 2023*. https://www.hm.ee/sites/default/files/documents/2023-12/PISA%202022%20Insights%20and%20Interpretations_OECD.pdf

Sellars, M., Fakirmohammad, R., Bui, L., Fishetti, J., Niyozov, S., Reynolds, R., Thapliyal, N., Liu-Smith, Y.-L., & Ali, N. (2018). Conversations on critical thinking: Can critical thinking find its way forward as the skill set and mindset of the century? In *Education Sciences* (Vol. 8, Issue 4, p. 205). https://doi.org/10.3390/educsci8040205

Selvaretnam, G. (2024). Facilitating feedback generation and group skill development through assessment design. *Journal of Work-Applied Management*. https://doi.org/10.1108/JWAM-10-2023-0103

Shore, A., & Dinning, T. (2023). Developing student's skills and work readiness: an experiential learning framework. *Journal of Work-Applied Management*, *15*(2), 188–199. https://doi.org/10.1108/JWAM-02-2023-0016

Sumartias, S., Unde, A. A., Wibisana, I. P., & Nugraha, A. R. (2020). The importance of local wisdom in building national character in the industrial age 4.0. *Advances in Social Science, Education and Humanities Research*, *397*(Icliqe 2019), 1305–1312. https://doi.org/10.2991/assehr.k.200129.159

Suriswo, Aulia, F., & Utami, W. B. (2023). Development of the life skills learning model for elementary school students as strengthening the Pancasila student profile. *JTP - Jurnal Teknologi Pendidikan*, *25*(2), 315–322. https://doi.org/10.21009/jtp.v25i2.37532

Syafi'i, F. F. (2021). Merdeka belajar: Sekolah penggerak. *Prosiding Seminar Nasional Pendidikan Dasar "Merdeka Belajar Dalam Menyambut Era Masyarakat 5.0," November*, 46–47. https://ejurnal. pps.ung.ac.id/index.php/PSNPD/article/view/1049

Syafii, W., & Yasin, R. M. (2013). Problem solving skills and learning achievements through problem-based module in teaching and learning biology in high school. *Asian Social Science*, *9*(12 SPL ISSUE), 220–228. https://doi.org/10.5539/ass.v9n12p220

Syahrial, S., Asrial, A., Kurniawan, D. A., & Pratama, R. A. (2019). Towards improving the critical thinking skills of pre-service teachers in Indonesia. *Journal of Education and Learning (EduLearn)*, *13*(4), 575–582. https://doi.org/10.11591/edulearn.v13i4.13613

Teo, T. W., Tan, A. L., Ong, Y. S., & Choy, B. H. (2021). Centricities of STEM curriculum frameworks: Variations of the S-T-E-M Quartet. *STEM Education*, *1*(3), 141. https://doi.org/10.3934/steme.2021011

Thuneberg, H. M., Salmi, H. S., & Bogner, F. X. (2018). How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module. *Thinking Skills and Creativity*, *29*, 153–160. https://doi.org/10.1016/j.tsc.2018.07.003

Tuamsuk, K. (2013). Information literacy instruction in Thai higher education. *Procedia - Social and Behavioral Sciences*, *73*, 145–150. https://doi.org/10.1016/j.sbspro.2013.02.034

Utomo, A. P., Hasanah, L., Hariyadi, S., Narulita, E., Suratno, & Umamah, N. (2020). The effectiveness of steam-based biotechnology module equipped with flash animation for biology learning in high school. *International Journal of Instruction*, *13*(2), 463–476. https://doi.org/10.29333/iji.2020.13232a

Yi, C., Zhu, R., & Wang, Q. (2021). Exploring the interplay between question-answering systems and communication with instructors in facilitating learning. *Internet Research*, *32*(7), 32–55. https://doi.org/10.1108/INTR-08-2020-0459

Ylostalo, J. H. (2020). Engaging students into their own learning of foundational genetics concepts through the 5E learning cycle and interleaving teaching techniques. *Journal of Biological Education*, *54*(5), 514–520. https://doi.org/10.1080/00219266.2019.1620311

Zhou, C. (2021). The effectiveness of 5E model to improve the scientific creativity of teachers in rural areas. *Thinking Skills and Creativity*, *41*(May), 100900. https://doi.org/10.1016/j.tsc.2021.100900