Effectiveness of Guided Inquiry Based Student Worksheet Integrated with Flipped Classroom System on Reaction Rate Material on Students' Ability to Think Critically

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Abstract: This research aims to determine the effectiveness of guided inquiry based student worksheet integrated with flipped classroom system on reaction rate material on students' ability to think critically. This is a further development research with the type of quasi experiment and research design Non-equivalent control group design. In this study, two sample classes were used, namely control class and experiment class with a total sample size of 71 people who were taken using purposive sampling technique. After conducting the research, it is known that the n-gain value for the control class is 0.3 and the experimental class is 0.57, the difference in n-gain value is inferred that there is a difference in treatment in the two sample classes on student critical thinking skills. Furthermore, for hypothesis testing, the t_{table} value is 1.995 and t_{count} value is 6.13. Based on the results of data analysis, it is concluded that the use of guided inquiry-based student worksheet integrated with the flipped classroom system is effective in enhancing student critical thinking skills.

Keywords: Critical thinking skills; Flipped classroom system; Guided inquiry; Reaction rate; Student worksheet.

Introduction

The industrial revolution 4.0 has an impact on all sectors of human life including education (Dito & Pujiastuti, 2021). This evolution is indicated by the use of technology that is synchronized to create opportunities that advance education. Therefore, 4 competencies were added to the education curriculum, namely critical thinking skills, creative and innovative skills, communication skills, and the ability to collaborate (Maulidah, 2019). This curriculum changes demand teachers and learners to be proficient in technology to answer the challenges in the industrial revolution era.

Learning in the era of revolution 4.0 draws on the use of technology-based media or devices (Surahman, 2019). The use of technology in the field of education has been used even before the covid-19 outbreak attacked the world. Covid-19 has spread since November 2019 causing changes in the order of human life including in the educational field (Samudera, 2020). Changes in the field of education lead to new problems that must be quickly resolved so that learning activities continue to be effective and one of the solutions applied is blended learning.

Blended learning refers to a study system that combines synchronous and asynchronous learning (Powell et al., 2015). There are two types of synchronous learning: online synchronous and offline synchronous.

The synchronous step is implemented directly by the teacher at school, whereas the asynchronous step is held outside of school with the help of technology as a media link between teachers and students. One model that implements both synchronous and asynchronous learning is the flipped classroom (Waer & Mawardi, 2021).

The flipped classroom refers to a way of learning system where students start learning material at home (asynchronous) and reinforce the concepts that have been acquired at school with the assistance of the teacher (synchronous) (Stein & Graham, 2014). In the asynchronous stage, the teacher prepares a video containing supporting information as a media to help students study at home (Syafei & Mawardi, 2022). In the synchronous stage, the teacher confirms the concepts that have been mastered by students during asynchronous (Lenggogeni & Mawardi, 2022). Asynchronous learning uses a Learning Management System (LMS) to support student activities while at home.

LMS is software used to carry out activities using internet technology. The LMS used in asynchronous learning is YouTube and WhatsApp. YouTube and WhatsApp applications help teachers to coordinate the class and help students to connect with other students in the network. The utilization of the flipped classroom system in learning activities is in sync with the purpose of the curriculum 2013, which is student centered activities (Hartandi & Mawardi, 2022). One of the learning models that focuses on students is guided inquiry (Nengsih & Mawardi, 2021).

Guided inquiry is a learning model that involves prior knowledge to build their own concept understanding by using 5 stages, namely orientation, exploration, concept formation, application, and closing (Hanson, 2005). Concept formation is a stage that determines the role of a teacher in helping students to find their own concepts. At this stage the teacher is required to make key questions that are able to direct students to find concepts independently. Guided inquiry is able to improve students' critical thinking skills because students must answer key questions to get concepts by exploring a model in the exploration stage (Hanson, 2013).

Critical thinking is a combination of mental processes, strategies, ways of solving problems, and learning new concepts (Kong, 2014). Critical thinking skills are needed so that students able to make decisions in solving given problems. In the 21st century, four skills need to be mastered: critical thinking and problem solving, communication, collaboration, creativity and innovation (Widana et al., 2018). According to Hayudiyani (2017) there are 6 aspects in critical thinking, namely interpretation, analysis, inference, evaluation,

explanation, self-regulation. Students' ability to think critically can be measured using HOTS questions at the C4-C6 level. These questions not only focus students on remembering, restating, or applying concepts but also to measure students' ability to connect several concepts to obtain information, find relationships from different information, use existing information to solve problems and critically analyze ideas and information (Setiawati et al., 2018).

The developed HOTS questions are used to measure the metacognitive dimension. The metacognitive dimension describes students' ability to connect different concepts, interpret and solve problems, choose the right strategy in solving problems, find new methods, argue and choose the right decision (Ariyana et.al, 2018). Critical thinking skills can be trained in the learning process during classroom activities.

Reaction rate is material that can help students' critical thinking skills because it is an abstract concept with concrete examples that require submicroscopic level solutions (Paramita et al., 2021). There are two basic competencies (KD) that must be learned in the reaction rate material KD 3.6 and 3.7. The primary objective of learning reaction rate is for students to be proficient in defining the concept of reaction rate, describing factors that affect reaction rate, and determining the order and rate of reaction. This material has three chemical multi-representations, namely macroscopic, submicroscopic, and symbolic (Sodanango et al., 2021).

This particular research is related to previous research, namely the effectiveness of the guided inquiry learning model integrated with the flipped classroom system on acid-base material to improve student learning outcomes (Lenggogeni & Mawardi, 2022) and buffer solutions (Hartandi & Mawardi, 2022) which shows the level of effectiveness at a high level. Another study that is also relevant to this research is the study conducted by Mawardi et al. on improving students' critical thinking skills using guided inquiry-based student worksheet on acid-base material which shows effectiveness at a medium-high level (Mawardi, Js, & Yani, 2020). Another related research is the development of a guided inquiry learning model integrated with the flipped classroom system by Pratiwi & Mawardi (2022) which shows high validity and practicality results.

This research is a extension of Ramadansyah & Mawardi (2021) development research which shows that the guided inquiry-based student worksheet integrated with the flipped classroom system has a level of validity and practicality with a value of 0.85 and 87%, so it can be concluded that this product is valid and practical. This research has not yet reached the stage of testing the effectiveness of student critical thinking skills. Therefore, this study aims to determine the effectiveness

of guided inquiry-based student worksheet integrated with the flipped classroom system on reaction rate material on students' ability to think critically.

Method

The effectiveness test uses a type of quasi experiment. Quasi experiment is research where other variables outside the variables studied cannot be controlled by the researcher (Sugiyono, 2013). Referring to the kind of research selected, the research design is a non-equivalent control group (Sugiyono, 2013). This research design involves two sample classes, namely the control class and the experimental class with a total sample of 71 people. This sampling was selected based on certain considerations and suggestions from experts so that the selection technique is called purposive sampling technique (Sugiyono, 2013). This research designs can be shown in Table 1.

Table 1. Non-equivalent control group design

Pretest	Treatment	Posttest
O_1	X	O_2
O_3	Y	O_4

Source: Sugiyono, (2013)

Description:
O_1: experimental class pretest
O_2: experimental class posttest
O_3: control class pretest
O_4: control class pretest
X: treatment

In order to determine students' critical thinking skills, a multiple choices test instrument at the c4-c6 level was used. This question consists of 15 multiple choice questions that have been tested for validity, reliability, difficulty index, and differentiation. After the research was completed, the data obtained was analyzed using the N-gain test, normality, homogeneity, and hypothesis testing.

Result and Discussion

The study results obtained after conducting research from September to October 2022 at SMAN 1 Banuhampu. The data collected was in the form of learning outcomes at the C4-C6 level of cognitive competence. This data was obtained through the initial assessment (pretest) and the final assessment (posttest) in class XI IPA 1 as the experimental class and class XI IPA 4 as the control class. Analysis of the data showed that the average value of the experimental class was higher than the control class this analysis can be seen in Figure 1.
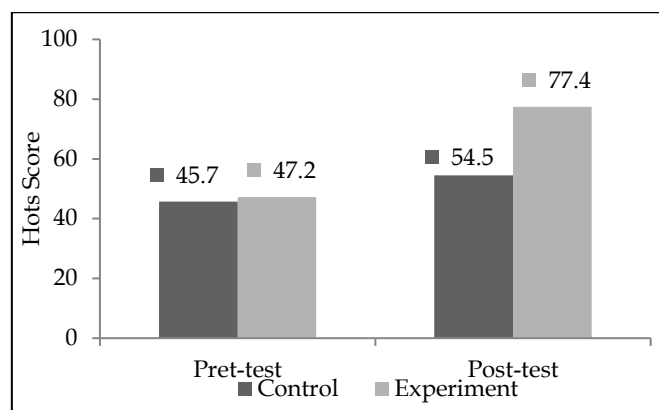

Figure 1. Data analysis sample class

Based on Figure 1, it is shown that the average increase in student learning outcomes in the cognitive domain with the HOTS question category in the experimental class is higher than in the control class. The experimental class has a difference in pretest and posttest scores of 30.2 and the control class has a difference in pretest and posttest scores of 8.8. This is because the treatment in the control class used textbooks while the experimental class used guided inquiry-based student worksheet integrated with the flipped classroom system written by Ramadansyah & Mawardi (2021).

After recognizing the average difference from the pre-test and post-test of the control and experimental classes. The next step is N-gain analysis. From the results of data analysis, the N-gain values for the control class and experimental class were 0.30 and 0.57. The difference in the value of the two samples concluded that the treatment provided had a beneficial effect on the critical thinking skills of the sample class students. The data obtained was then tested for normality using the Kolmogorov-Smirnov method and homogeneity test using Levene's statistics. The results of the test indicate that the data is normally distributed and homogeneous.

The next step is to test the hypothesis using the t-test. Hypothesis testing using t-test is done if the data is normally distributed and homogeneous. After analyzing the data, it is known that the t_{count} value in hypothesis testing is 6.13 and the t_{table} value is 1.997. the data analysis results prove that H0 is rejected and H1 is accepted. H1 is accepted, meaning that the implementation of guided inquiry-based student worksheet has an impact on students' higher order thinking skills.

This guided inquiry student worksheet writes the material following the steps of the guided inquiry model. Guided inquiry has five syntaxes, namely orientation, exploration, concept formation, application, and closing. Then the student worksheet combined with the flipped classroom system. Flipped classroom is a learning system that applies synchronous and

asynchronous learning. Flipped classroom makes activities that are usually performed at school into activities that are performed at home. Flipped classroom system learning based on guided inquiry has two stages, namely the orientation and concept formation stage before the face-to-face class begins (asynchronous) and the stage related to the reinforcement of concepts carried out in the classroom (synchronous).

Asynchronous learning using WhatsApp learning management system (LMS) to share videos that have been made by the teacher which are placed on the YouTube platform. The video that was given by the teacher contained an orientation to the learning material that would be learned during the synchronous class. The learning process using the guided inquiry learning model integrated with the flipped classroom system can be seen in Figure 2.
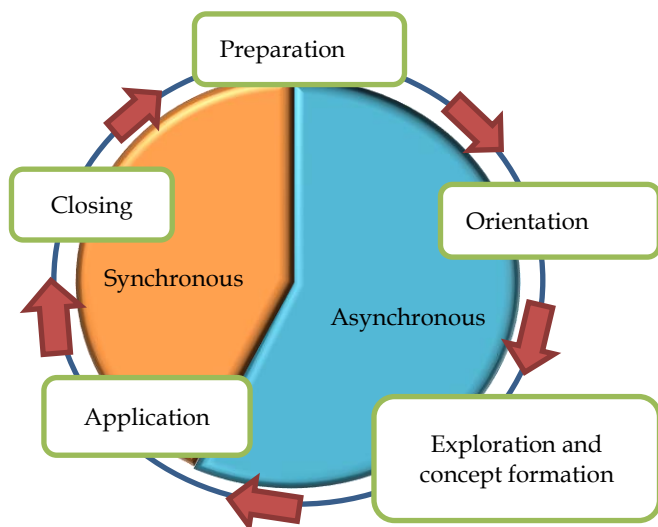

Figure 2. Guided inquiry learning on flipped classroom Sources: (Ramadhansyah & Mawardi, 2021)

The orientation stage is a stage that contains prerequisite material that must be mastered by students before entering the core material. At this stage students must watch the video that has been shared on YouTube. The orientation video consists of greetings, motivation, apperception, basic competencies, learning objectives and prerequisite material designed by the teacher and uploaded to the YouTube platform. At this stage students can watch videos anywhere without any time limit (Iqbal & Mawardi, 2022). The next stage is the exploration stage. The exploration stage is the stage where students explore their ability to find concepts through the models given in the student worksheet. One of the models shown in the orientation stage can be in Figure 3.
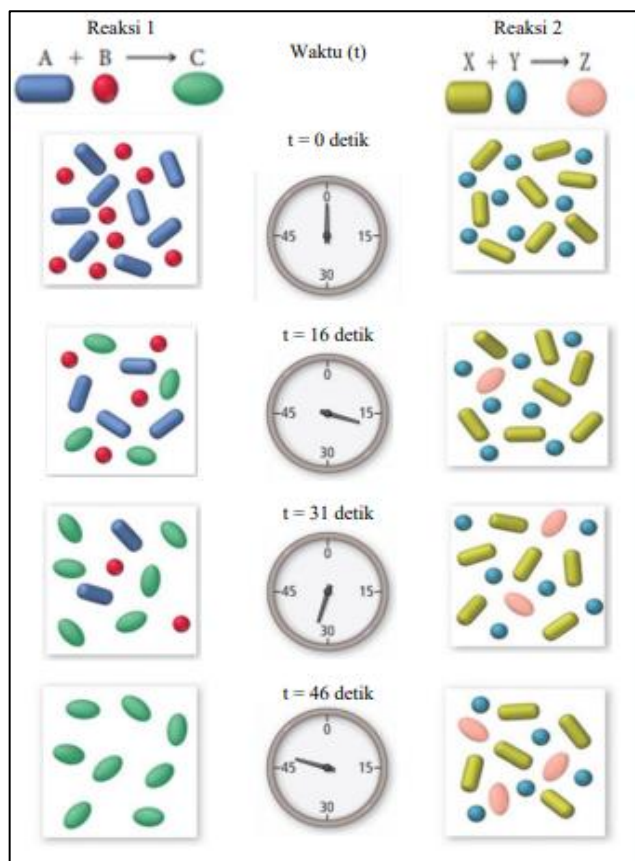

Figure 3. Fast and slow reaction models Sources: (Ramadhansyah & Mawardi, 2021)

Figure 3 explains the concept of reaction rate. The reaction rate is the process of reducing the concentration of reactants and the process of increasing the concentration of products per unit time (Chang, 2011). The number of experimental class students was 36 people arranged into 6 groups, and one person from each group was used as a representative to compare answers related to the model in the LKPD. The results of the group representative's answers can be seen in the following table 2.

According to the table above, it can be inferred that student 4 has a good understanding of the model given. This is evident from the conclusion obtained in accordance with the definition of the reaction rate, which is the change in concentration of reactants and products per unit time. Meanwhile, students 1,2,3,5, and 6 have also almost well understood the model, this is shown in the answers given. Therefore, it can be concluded that students can explore and understand concepts well if they are able to answer questions, think critically and creatively.

Table 2. Group representative's response to figure 3

Sample	Each group representative's answer
Student 1	Based on the model in Figure 2, the higher the concentration of the reacted substances, the greater the reaction rate.
Student 2	According to the model in Figure 2, the increase in the concentration of the reacted substance, the greater the reaction rate and the less the reacted substance, the slower the reaction rate.
Student 3	Based on the model in Figure 2, the size of the reaction rate depends on the substance concentration
Student 4	Referring to the model in Figure 2, the reaction rate is the change of reactants to products per unit time.
Student 5	Referring to the model in Figure 2, the reaction rate is a measure of how rapidly/slowly the reaction products are formed.
Student 6	Based on the model in Figure 2, the reaction rate is a measure of how fast/slow the reaction product is formed.

Application is a stage that is run face-to-face at school. This stage is the reinforcement stage of the concepts that students have already discovered in the exploration and concept formation steps. During this stage, students will answer several questions that have been designed to further explore students' understanding of the concepts that have been gained in the previous stage. At this stage students also work in groups. The presence of group learning will involve students playing an active role in learning that emphasizes data analysis and critical thinking. If students understand the concepts found in the exploration and concept formation stages, they will also be successful in answering questions at the application stage. One of question provided in this stage can be shown in table 3.

Based on the table above, the questions designed are used to explore further the concepts that have been gained in the previous stage. At this stage, 95% of the sample answered correctly. It is summarized that almost all samples were able to explain the concept of reaction rate.

The last step is closing this stage also apply in the classroom face-to-face with the teacher. At this stage students will present the concepts that have been obtained in the previous step. After the presentation session ends, it will be followed by a question and answer session from other students to the presentation group. During this activity, the teacher only acts as a facilitator who organizes the presentation so that it runs well. After the question and answer session is over, the teacher and students will strengthen and confirm the concepts that have been obtained by students before.

The use of a flipped classroom system by implementing a guided inquiry model is useful for optimizing time in class (Nuryadin et al., 2021). Collaboration between asynchronous and synchronous learning makes the time required by students to learn and understand the material more. Furthermore, the use of technology as a media in asynchronous learning allows students to learn anytime and anywhere. One of the factors that influence critical thinking skills is learning independence (Dores et al., 2020). This factor is in line with the guided inquiry-based flipped classroom system where students are required to be independent in finding learning concepts. The benefits presented are directly proportional to the student learning outcomes that have been obtained in the study, which is 0.57 in the medium-high category.

Table 3. Question in application stage

Number	Question
1	If it is assumed that the volume of the tube is 2 liters and the avogadro constant is 6.02×10^{23} whereas the number of product particles formed is 12×10^{23}. Convert the number of product particles formed into molarity?
2	In chemistry practicum, the following reaction occurs $$2N_2O_5 \rightarrow 4NO_{2\,(g)} + 2O_{2\,(g)}$$ After the reaction has gone on for 10 seconds, it is known that N_2O_5 is reduced from 2 mole/L to 0.5 mole/L. What is the reaction rate of the reduction of N_2O_5?

Conclusion

This research proves that the guided inquiry-based student worksheet integrated with the flipped classroom system is effective for enhancing students' critical thinking skills. This can be seen from N-gain analysis and hypothesis testing. The n-gain for the control class and experimental class were 0.3 and 0.57 which were in the medium-high category. Hypothesis testing t' for the experimental class and control class found that t_{table} 1.997 and t_{count} 6.13, this value indicates that H1 is accepted and Ho is refused. The enhancement of students' critical thinking skills is the main target for assessing the effectiveness of guided inquiry student worksheets and this is also in line with the demands of the curriculum 2013.

Author Contribution

References

Ariyana, Y., Pudjiastuti, A., Bestary, R., & Zamroni. (2018). *Buku Pegangan Pembelajaran Keterampilan Berpikir Tingkat Tinggi Berbasis Zonasi*. Jakarta: Direktorat Jenderal Guru Dan Tenaga Kependidikan Kementrian Pendidikan Dan Kebudayaan.

Dito, S. B., & Pujiastuti, H. (2021). Dampak Revolusi Industri 4.0 Pada Sektor Pendidikan: Kajian Literatur Mengenai Digital Learning Pada Pendidikan Dasar dan Menengah. *Jurnal Sains Dan Edukasi Sains, 4*(2), 59–65. https://doi.org/10.24246/juses.v4i2p59-65

Dores, O. J., Wibowo, D. C., & Susanti, S. (2020). Analisis Kemampuan Berpikir Kritis Siswa Pada Mata Pelajaran Matematika. *J-PiMat: Jurnal Pendidikan Matematika, 2*(2), 242–254. https://doi.org/10.31932/j-pimat.v2i2.889

Hanson, D. M. (2005). *Designing Process-Oriented Guided Inquiry Activities (2nd ed.)*. Cananda: Pacific Crest.

Hanson, D. M. (2013). *Instructor's Guide To Process Oriented Guided Inquiry Learning*. New York: Pacific Crest.

Hartandi, M., & Mawardi. (2022). Effectiveness Of The Guided Inquiry-Based Flipped Classroom Learning System On Buffer Solution. *JKPK (Jurnal Kimia Dan Pendidikan Kimia), 7*(2), 194–207. https://doi.org/10.20961/jkpk.v7i2.63618

Hayudiyani, M., Arif, M., & Risnasari, M. (2017). Identifikasi Kemampuan Berpikir Kritis Siswa Kelas X TKJ. *Jurnal Ilmiah Edutic, 4*(1), 20–27. https://doi.org/10.21107/edutic.v4i1.3383

Iqbal, M., & Mawardi. (2022). Flipped Learning Model - Guided Inquiry Learning (FGIL) for Digital Learning for First Year Chemistry Students. *Jurnal Pendidikan Ipa, 8*(4), 1719–1723. https://doi.org/10.29303/jppipa.v8i4.1633

Kong, S. C. (2014). Developing information literacy and critical thinking skills through domain knowledge learning in digital classrooms: An experience of practicing flipped classroom strategy. *Computers and Education, 78(1)*, 160–173. https://doi.org/10.1016/j.compedu.2014.05.009

Lenggogeni, K., & Mawardi. (2022). Effectiveness of a Flipped Classroom Based on Guided Inquiry Learning System on Acid-Base Solutions. *Jurnal Pendidikan Ipa, 8*(4), 2168–2175. https://doi.org/10.29303/jppipa.v8i4.1909

Maulidah, E. (2019). Character Building Dan Keterampilan Abad 21 Dalam Pembelajaran Di Era Revolusi Industri 4.0. *Prosiding Seminar Nasional PGSD UST*, 1. Retrieved from https://jurnal.ustjogja.ac.id/index.php/sn-pgsd/article/view/4740

Mawardi, M., Js, A. F. R., & Yani, F. H. (2020). Effectiveness of student worksheets based guided inquiry on acid base material to improve students higher order thinking skill (HOTS). *Journal Of Physics: Conference Series, 1481*(1), 1–5. https://doi.org/10.1088/1742-6596/1481/1/012083

Nengsih, Z. W., & Mawardi, M. (2021). Pengembangan Sistem Pembelajaran Flipped Classroom Berbasis Inkuiri Terbimbing pada Materi Hidrolisis Garam. *EDUKATIF: Jurnal Ilmu Pendidikan, 3*(4), 1231–1244. https://doi.org/10.31004/edukatif.v3i4.546

Nuryadin, A., Rijal, M., Muharram, W., & Guntara, R. G. (2021). Penggunaan Model Flipped Classroom Berbantuan Digital Tools Untuk Meningkatkan Kyalitas Pembelajaran di Sekolah Dasar Selama Pandemi Covid-19. *Journal Of Elementary Education, 4*(3), 348–361. https://doi.org/10.22460/collase.v4i3.7100

Paramita Kinantya, A., Yahmin, Y., & Dasna, I. W. (2021). Pembelajaran Inkuiri Terbimbing dengan Pendekatan STEM (Science, Technology, Engineering, Mathematics) untuk Pemahaman Konsep dan Keterampilan Argumentasi Siswa SMA pada Materi Laju Reaksi. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan, 5*(11), 1652–1663. https://doi.org/10.17977/jptpp.v5i11.14189

Powell, A., Watson, J., Staley, P., Patrick, S., Horn, M., Fetzer, L. Verma, S. (2015). *Blending Learning: The Evolution of Online and Face-to-Face Education from 2008–2015*. USA: The International Association for K–12 Online Learning. Retrieved from http://files.eric.ed.gov/fulltext/ED560788.pdf

Pratiwi, D., & Mawardi. (2022). Development Guided Inquiry-Based Flipped Classroom Learning System for Industrial Revolution 4.0 Era on Chemical Bonding Material Using LMS Moodle. *Pancaran Pendidikan FKIP Universitas Jember, 11*(3), 41–54. https://doi.org/10.25037/pancaran.v11i3.399

Ramadhansyah, & Mawardi, M. (2021). Development Of

Guided Inquiry-Based Flipped Classroom Learning System On Reaction Rate For 11 th Grade Senior High School Students. *Internationa Journal Of Progresive Sciences and Technologies (IJPSAT), 27*(2), 597–601. https://doi.org/10.52155/ijpsat.v27.2.3339

Samudera, W. (2020). Dampak Pandemi Covid-19 Dalam Bidang Pendidikan Di Kota Mataram. *Indonesian Journal Of Teacher Education, 1*(3), 154–158. https://doi.org/10.1016/j.pbi.201

Setiawati, W., Asmira, O., Ariyana, Y., & Bestary, R. (2018). *Buku Pegangan Pembelajaran Berorientasi Pada Keterampilan Berpikir Tingkat Tinggi*. Jakarta: Direktorat Jenderal Guru dan Tenaga Kependidikan Kementerian Pendidikan dan Kebudayaan.

Sodanango, P. Y., Munzil, M., & Sumari, S. (2021). Analisis Model Mental Peserta Didik SMA dalam Memahami Konsep Laju Reaksi. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan, 6*(10), 1543. https://doi.org/10.17977/jptpp.v6i10.15048

Stein, J., & Graham, C. R. (2014). *Online & Blended Learning: Selections From The Field.* New york: Routledge Taylor & Francis Group.

Sugiyono. (2013). *Metode Penelitian Kuantitif, Kualitatif dan R&D*. Bandung: Alfabeta.

Surahman, E. (2019). Pengembangan Inovasi Pembelajaran Digital Menggunakan Model Blended POE 2 WE di Era Revolusi Industri 4.0. *Seminar Nasiona Fisika Dan Aplikasinya*, *1*(1), 82–90. https://doi.org/10.20961/prosidingsnfa.v4i0.35915

Syafei, S. S., & Mawardi, M. (2022). POGIL Model Integrated Flipped Classroom Assisted Learning Management System (LMS) for Learning Solution in ERI 4.0. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 444–451. https://doi.org/10.29303/jppipa.v8i2.1298

Waer, W. P., & Mawardi, M. (2021). Integrasi Model Inkuiri Terbimbing Dan Pendekatan Flipped Classroom Pada Pembelajaran Materi Sifat Koligatif Larutan Untuk Siswa Kelas XII SMA/MA. *EDUKATIF: Jurnal Ilmu Pendidikan*, *3*(3), 1029–1037. https://doi.org/10.31004/edukatif.v3i3.498

Widana, I. W., Parwata, I. M. Y., Parmithi, N. Y., Jayantika, I. G. A. T., Sukendra, K., & Sumandya, I. W. (2018). Higher Order Thinking Skills Assessment towards Critical Thinking on Mathematics Lesson. *International Journal of Social Sciences and Humanities (IJSSH)*, *2*(1), 24–32. https://doi.org/10.29332/ijssh.v2n1.74