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Effectiveness of Problem-Based Learning with Dr Stone Animation on Grade XI Students' Acid-Base Learning Outcomes

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Abstract

The background of this research is low student performance in the topic and the need for an innovative, interactive, and contextual learning approach. This study aims to examine the effectiveness of the Problem-Based Learning (PBL) model using Dr Stone's animation media on students' learning outcomes in the acid-base topic for Grade XI students at SMA Negeri 1 Sirenja. The problem addressed in this research relates to how to improve student learning outcomes and engagement through the integration of contextual and technology-based media. The research employed a pre-experimental design with a one-group pre-test and post-test on a single experimental class consisting of 30 students. The instruments used included Lesson Plans (RPP), Student Worksheets (LKPD), Dr Stone animation media, and a multiple-choice learning outcome test consisting of 15 validated questions, reviewed and approved by expert validators. The validation results showed that all instruments were valid and appropriate for use. Student learning outcomes were analysed using the N-Gain score to measure the improvement after learning. The average N-Gain score was 0.7331 (73.31%), placing it in the moderately effective category. The average difference between pre-test and post-test scores was 37.10 points, indicating a significant improvement in student learning outcomes. Most students experienced substantial learning gains after participating in problem-based learning supported by animation media. This study demonstrates that combining the Problem-Based Learning (PBL) model with Dr Stone's animation media effectively improves student learning outcomes. Furthermore, this study supports the learning process by incorporating a contextual and interactive approach that fosters students' motivation, deepens their conceptual understanding, and promotes active involvement in chemistry lessons. It also offers valuable guidance for teachers on applying technology-integrated, student-centred teaching strategies in science education.

Keywords: Dr Stone animation; innovative learning; learning outcomes; teaching strategy

Introduction

Education is the fundamental foundation for shaping the character, knowledge, and skills of the younger generation, both intellectually and morally. Effective learning is the key to ensuring that the teaching and learning process runs optimally. One way teachers can encourage students to be more active in the learning process is to implement varied and innovative learning models (Marselina et al., 2024). With the right combination of methods and media, the learning atmosphere becomes more engaging, thereby improving students' learning outcomes (Anam et al., 2023). The two main components of the learning process are the learning model and the learning media. A learning model serves as a framework for achieving learning objectives by emphasising creativity, critical thinking, communication, and collaboration in line with 21st-century demands (Juniantari & Suniasih, 2023). One effective learning model is Problem-Based Learning (PBL), which aims to develop critical thinking through solving real-world problems, making the knowledge gained more meaningful (Pradani & Supardi, 2023).

Problem-Based Learning (PBL) is grounded in constructivist theory, where students actively construct knowledge through experience and reflection (Sarnoko et al., 2024). PBL creates a learning environment that requires students to participate in solving complex, contextual problems (Arsyad et al., 2024). This method allows students to connect prior knowledge with new information, encouraging active and meaningful learning (Affandy et al., 2024). Moreover, PBL fosters critical thinking, teamwork, and problem-solving skills that are essential for the 21st century (Ikbal, 2021). However, several studies have noted that implementing PBL in chemistry instruction often faces challenges due to students' limited conceptual understanding and difficulty visualising abstract concepts (Winarti et al., 2024).

One of the abstract concepts in chemistry that students often struggle to understand is the

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theory of acids and bases, including pH, neutralisation, and ionization (Defista & Aznam, 2024). Mastery of this material is crucial for higher-level chemistry topics and for applying scientific principles in daily life. However, due to its abstract nature, traditional teaching methods are often insufficient to promote conceptual understanding (Sari et al., 2024). The use of learning media, especially animation, plays a vital role in improving comprehension and retention. Animations can transform abstract chemical reactions into visual, concrete representations, making learning more engaging. Among these, Dr Stone, a science-themed animation, creatively integrates chemistry concepts into an engaging storyline about rebuilding civilisation through science (Anam et al., 2023). This contextually rich visualisation makes Dr Stone highly suitable for explaining acid–base concepts and demonstrating their relevance to real-world phenomena (Fiori & Goi, 2022).

Integrating PBL with Dr Stone's animation offers an innovative approach to contextual learning (Septaria & Fatharani, 2022). PBL promotes problem-solving and inquiry, while Dr Stone provides visual and narrative support to enhance understanding. This integration is expected to address both cognitive and motivational challenges in chemistry education. Previous studies between 2021 and 2025 have shown that PBL improves students' critical thinking (Khoiriyatul & Aziz, 2025; Paramita & Setyono, 2024), and animation media increases engagement and conceptual understanding (Azizah & Kamaludin, 2023). However, only a few studies have combined both strategies, particularly using contextualised science animations that directly illustrate chemical principles. This reveals a gap in the existing literature that this study aims to address by exploring how combining PBL with Dr Stone's animation can simultaneously improve learning outcomes and engagement with acid–base material.

SMA Negeri 1 Sirenja was selected as the research site based on several considerations. First, interviews conducted in April 2024 revealed that many students struggled with acid–base material and failed to meet the Minimum Mastery Criteria (KKM) of 65. This indicates the need for innovative instructional strategies to improve comprehension. Second, the school implements the 2013 Curriculum, which emphasises active, competency-based learning, thereby aligning with PBL (Septianingsih et al., 2024). Third, teachers at the school are open to integrating digital learning media, such as animations, into classroom instruction. Based on this background, this study aims to determine the effectiveness of applying the Problem-Based Learning (PBL) model using Dr Stone's animation as a learning medium on students' learning outcomes in the topic of acids and bases at SMA Negeri 1 Sirenja.

Methods

Research design

This research employed an experimental method in the form of classroom treatment. Experimental research is defined as a research method used to examine the effectiveness of a particular treatment compared to another under controlled conditions. The type of experiment applied in this study is a pre-experimental design, which is not considered a true experiment because external variables may still influence the dependent variable due to the absence of control variables (Widiastuti & Hermanto, 2024).

The pre-experimental design used was the one-group pre-test and post-test design, as shown in **Table 1.**

Table 1. One-group pretest-posttest design

Pretest	Treatment	Posttest
O_1	X	O_2

(Sugiyono, 2021)

Description:

O_1 = Pre-test score (before treatment)

X = Treatment using the Problem-Based Learning (PBL) model with Dr Stone's animation media

O_2 = Post-test score (after treatment)

The population in this study consisted of Grade XI MIPA students at SMA Negeri 1 Sirenja, totalling 117 students across 4 classes. The sample, class XI MIPA 4 (30 students), was purposively selected based on teacher recommendations and prior exam results showing lower achievement than other classes (Purnawan, 2022).

Data collection technique

The research was conducted in three main phases: preparation, implementation, and finalisation. In the preparation phase, activities included observing the research site and consulting with the chemistry teacher to understand the teaching context thoroughly. The population and the sample were purposively selected based on academic performance and teacher recommendations. In the implementation phase, students first took a pre-test to measure their initial understanding. The PBL model integrated with Dr Stone's animation media was then applied during learning activities to promote active engagement and contextual understanding. Following this, a post-test was conducted to assess improvement in learning outcomes. The teaching intervention was carried out over four meetings, including an introduction, treatment, and evaluation. Each session followed a teaching module and a Student Worksheet (LKPD) designed according to the PBL model's syntax. This design aligns with recent science education research employing pre-test and post-test methods to evaluate PBL effectiveness. In the final phase, data from pre-tests and post-tests were collected, analysed, and interpreted to prepare the final research report.

Research instruments

The research instruments used in this study consisted of instructional devices and test instruments. Instructional devices included Lesson Plans (RPP), Student Worksheets (LKPD), and Dr Stone animation media, all specifically designed to align with the Problem-Based Learning (PBL) model and the acid-base curriculum. These devices provided step-by-step guidance for both teachers and students to support the implementation of the learning process. The test instruments consisted of a multiple-choice learning outcome test comprising 15 validated questions, which were used for both the pre-test and post-test. Expert validation was conducted for all instructional instruments to ensure their feasibility and accuracy (Zayrin et al., 2025).

This validation process is crucial, as emphasised by Pradani & Supardi (2023) and supported by recent studies highlighting the importance of expert review in establishing content validity for chemistry test instruments. Thus, the instructional devices and test instruments used in this study are considered feasible and reliable for evaluating the effectiveness of the PBL model integrated with Dr Stone's animation media in acid-base learning. The validity of these instruments was quantified using percentage scores. The validation criteria are presented in **Table 2.**

Table 2. Teaching module validation criteria

Validation criteria (%)	Validation Level
85.01-100.00	Very valid or can be used without revision
70.01-85.00	Valid or usable, but needs minor revisions.
50.01-70.00	It is less valid; it is recommended not to use it because it needs a major revision.
1.00-50.00	Invalid and should not be used

(Fatmawati, 2016)

Data analysis techniques

The effectiveness of the instructional intervention was evaluated using the Normalised Gain (N-Gain) formula:

$$\text{N-Gain}=\frac{(Posttest\ Score-Pretest\ Score)}{(100-Pretest\ score)} \quad (1)$$

N-Gain values were interpreted according to Hake's (1998) criteria: high (≥ 0.70), moderate (0.30 – 0.69), and low (< 0.30). Recent research confirms that N-Gain analysis is a reliable method for assessing improvements in students' conceptual understanding in science subjects.

N-Gain scores provide a quantitative measure of the effectiveness of the PBL model integrated with animation media, indicating whether students' comprehension significantly improved following the intervention. The instruments used in this study were multiple-choice tests for both pre-test and post-test, with data analysed descriptively to depict the distribution of results and inferentially using the N-Gain score to determine the effectiveness of the instructional treatment in enhancing students' understanding of acid-base material.

Results and Discussion

This study produced data on students' learning outcomes and an evaluation of the learning process, carried out through the implementation of the Problem-Based Learning (PBL) model, assisted by Dr Stone's animation media on the topic of Acids and Bases, in Grade XI MIPA 4 of SMA Negeri 1 Sirenja.

Validation of learning instruments

The validation results for the learning instruments indicated that all were valid and feasible for use. The details are presented in **Table 3.**

Table 3. Validation results of the learning instrument

Instrumen	Validation Score (%)	Category
Lesson Plan (RPP)	83.92	Valid
Student Worksheet (LKPD)	77.77	Valid
Dr Stone Animation Media	81.66	Valid
Learning Outcomes Test (Pre-test & Post-test)	80.76	Valid

All instruments exceeded the minimum validity threshold of 70%, indicating they were appropriate for classroom implementation. The high validity score of the *Dr Stone* animation media (81.66%) indicates that the visual content and narrative alignment were pedagogically relevant to chemistry learning, particularly in illustrating acid–base reactions that are difficult to observe directly.

Student learning outcomes

Pretest and posttest

The initial test was conducted to assess students' abilities before the acid–base titration learning process began. Meanwhile, the final test was conducted to determine the students' learning outcomes after implementing the Problem-Based Learning model and the Dr Stone animation media. The pretest and posttest results are presented in **Table 4.**

Table 4. Pretest and posttest score

Statistics	Pretest	Posttest
Min. Score	33	73
Max. Score	66	100
Mean (Average)	49.2	86.3

The results indicate a substantial improvement in student performance. The mean score increased from 49.2 in the pretest to 86.3 in the posttest, showing that the learning treatment effectively enhanced students' understanding and learning outcomes.

N-Gain analysis result

The pre-test and post-test results were analysed using the N-Gain test to assess the effectiveness of implementing the PBL model supported by Dr Stone's animation media. The N-gain test can demonstrate that the discovery learning model improves cognitive learning outcomes. The N-gain test is conducted by describing the data obtained based on the achievement of each variable in the relationship between students' pretest and posttest scores in the experimental class. The results of the N-gain calculation are shown in **Table 5.**

Table 5. N-Gain score and N-Gain percentage

Variabel	N	Minimum	Maximum	Mean	Category
N-Gain Score	30	0.43	1.00	0.73	High
N-Gain Percentage (%)	30	42.55	100.00	73.31	Medium

The improvement in students' learning outcomes was demonstrated by an increase in the average score, as indicated by the N-Gain analysis, which showed an N-Gain range of 0.43 to 1.00, with an average of 0.73 (high category), and an average N-Gain percentage of 73.31% (moderate category). According to Hake's criteria, this value falls into the high category, indicating that the PBL model combined with animation media was highly effective in improving students' conceptual mastery. This result was achieved through the systematic use of instructional tools, including student worksheets (LKPD), consistent test instruments, and integrated animation media across all learning stages. The LKPD guided students step by step through problem identification, hypothesis formulation, data collection, and solution presentation. The worksheets contained contextual problems and open-ended questions that encouraged critical thinking in accordance with PBL steps. In the LKPD used, the questions were problem-based and encouraged students to observe phenomena, analyse data, and draw independent conclusions. For instance, students were asked to observe colour changes of indicators in various solutions, determine whether the solutions were acidic or basic, and then explain these differences based on ionisation theory and H^+/OH^- ion concentration. These questions required students to connect theoretical concepts with real phenomena, complete observation tables, answer analytical questions, and construct scientific arguments systematically, following PBL syntax from problem orientation to solution presentation. This aligns with the findings of Febriana et al. (2024), who reported that PBL-based LKPD improves problem-solving skills and chemistry learning outcomes, supported by Safirah et al. (2024), who found that structured HOTS-oriented worksheets enhance critical thinking and student engagement in science learning.

The same test instrument was administered before and after instruction to measure students' conceptual development consistently. The questions assessed cognitive skills at various levels, ranging from identifying acid-base properties and comparing expert definitions to analysing pH changes and calculating Ka and Kb based on contextual data. The alignment between contextual LKPD questions and the evaluation items ensured that students not only recalled concepts but also transferred and reapplied knowledge to similar situations at a deeper level. This approach is consistent with the findings of Zakiyah et al. (2024), who confirmed that tiered assessments aligned with learning activities effectively measure the development of critical and conceptual thinking skills. Thus, the combination of problem-based questioning and consistent evaluation became one of the main factors contributing to the significant increase in N-Gain scores.

In addition to support from the LKPD and assessment system, the use of Dr Stone animation served as cognitive scaffolding by visualising microscopic processes such as ionisation, the release of H^+/OH^- ions, and the formation of conjugate acid-base pairs, making abstract concepts more concrete and comprehensible. This aligns with Mayer's Multimedia Learning Theory, which states that visualisation supports dual coding and reduces cognitive load, thus improving deep understanding and long-term retention. Consistent animation also increased student motivation and engagement, thereby strengthening learning outcomes. Even students with low initial ability demonstrated significant improvement, with N-Gain values reaching 1.00, indicating the effectiveness of scaffolding and collaboration in accordance with Vygotsky's Zone of Proximal Development (ZPD) (Ibrahim et al., 2023).

Overall, the improvement in learning outcomes was both quantitative, as shown by increases in test scores, and qualitative, as reflected in enhanced higher-order thinking skills such as analysis, synthesis, and evaluation. This confirms that integrating PBL, problem-based LKPD, digital animation, and consistent assessment effectively strengthens conceptual understanding, motivation, and critical thinking skills—aligned with constructivist principles and relevant to 21st-century learning, as affirmed by Hidayat et al. (2025).

The difference between the N-Gain score and the N-Gain percentage occurs because they use different interpretation scales, even though they measure the same improvement. The N-Gain score is calculated on a 0 – 1 scale using Hake's criteria, whereas the N-Gain percentage is expressed in percentage form with different categorical boundaries. Consequently, one indicator may fall into the "high" category, while the percentage N-Gain falls into the "moderate" category. This discrepancy is normal and has been explained in the literature (Hake, 1998), which emphasises that categorical interpretations may differ while still reflecting consistent improvement. In this study, both indicators continue to show substantial and consistent improvement in students' mastery of chemistry concepts.

Conclusions

Based on the results, the implementation of the Problem-Based Learning (PBL) model, assisted by Dr Stone's animation, is effective in improving students' learning outcomes in acids and bases. This effectiveness is reflected in the increased conceptual understanding, critical thinking skills, and active student engagement throughout the learning process. The systematic application of PBL steps supports this improvement, as does the use of problem-based worksheets and animations that visualise abstract concepts, making them easier to understand. Thus, integrating PBL and animation has proven successful in strengthening students' conceptual understanding, motivation, and participation in learning, in accordance with the research objective.

Conflict of Interest

There is no conflict of interest in this study.

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References

Affandy, H., Sunarno, W., Suryana, R., & Harjana. (2024). Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. *Thinking Skills and Creativity,* 53(September), 1–12. https://doi.org/10.1016/j.tsc.2024.101575

Anam, I. C., Zuhdi, A., & Fatiatun. (2023). Penerapan model pembelajaran problem based learning dengan bantuan animasi Dr. Stone untuk meningkatkan kemampuan berpikir kritis siswa SMK Karya Mandiri NU Garung. *Jurnal Review Pendidikan dan Pengajaran, 6*(4), 3443–3448. https://doi.org/10.31004/jrpp.v6i4.22518

Arsyad, M., Guna, S., & Barus, S. (2024). Enhancing chemistry education through problem-based learning: Analyzing student engagement, motivation, and critical thinking. *International Journal of Curriculum Development, Teaching and Learning Innovation*, *2*(3), 110-117. https://doi.org/10.35335/curriculum.v2i3.178

Azizah, N., & Kamaludin, A. (2023). Powtoon learning media contextually based on Thermochemistry materials to increase students' learning motivation. *Indonesian Journal of Science and Mathematics Education, 06*(3), 452–468. https://doi.org/10.24042/ijsme.v6i3.19547

Defista, C., & Aznam, N. (2024). Chemistry-focused conceptual understanding research trends: A systematic review. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 180-187. https://doi.org/10.29303/jppipa.v10i4.6534

Fatmawati, A. (2016). Pengembangan perangkat pembelajaran konsep pencemaran lingkungan menggunakan model pembelajaran berdasarkan masalah untuk SMA kelas X. *EduSains: Jurnal Pendidikan Sains dan Matematika,* 4(2). 94–103. https://doi.org/10.23971/eds.v4i2.512

Febriana, B. A., Masitah, S., & Satriawan, M. A. (2024). Development of problem based learning student worksheet on chemical bonding materials. *Jurnal Riset Ilmu Pendidikan*, *4*(4), 249-254. https://doi.org/10.56495/jrip.v4i4.930

Fiori, R., & Goi, M. E. J. (2022). Study of Chemistry through the digital culture of the anime Dr. Stone: a pedagogical proposal. *Research, Society and Development*, *11*(7), 1–12. http://dx.doi.org/10.33448/rsd-v11i7.30110

Hake, R., R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics,* 66(1), 64–74. https://doi.org/10.1119/1.18809

Hidayat, N., Wakhinuddin., Lapisa, R., Giatman, M., Dewi, I. P., Sardi, J., & Muriban, J. (2025). Effectiveness of the PBLMAR model in improving student learning outcomes: An N-gain analysis in air conditioning technology course. *Data and Metadata, 4*(958), 1–11. https://doi.org/10.56294/dm2025958

Ibrahim, K. A. A., Carbajal, N. C., Zuta, M. E. C., & Bayat, S. (2023). Collaborative learning, scaffolding-based instruction, and self-assessment: impacts on intermediate EFL learners' reading comprehension, motivation, and anxiety. *Language Testing in Asia, 13*(16), 1–33. https://doi.org/10.1186/s40468-023-00229-1

Ikbal, M. S. (2021). Pengaruh model problem based learning (PBL) berbasis children learning in science (CLIS) terhadap motivasi belajar peserta didik. *Karst: Jurnal Pendidikan Fisiska dan Terapannya,* 4(2), 50–61. https://doi.org/10.46918/karst.v4i2.1127

Juniantari, N. L. P., & Suniasih, N. W. (2023). Problem based learning model assisted by visual media improves critical thinking skills of grade IV elementary school students. *Thinking Skills and Creativity Journal, 6*(1), 76–85. https://doi.org/10.23887/tscj.v6i1.62587

Khoiriyatul, F. N., & Aziz, A. (2025). The effectiveness of problem-based learning assisted by animated videos in improving critical thinking skills. *Jurnal Profesi Keguruan,* 10(1), 49–65. https://doi.org/10.15294/jpk.v11i1.10861

Marselina, M. S., Kopon, A. M., & Tinenti, Y. R. (2024). Efektivitas penerapan model pembelajaran berbasis masalah (PBL) materi asam basa untuk meningkatkan hasil belajar peserta didik kelas XI IPA 5. *Jurnal βeta Kimia, 4*(2), 41–49. https://doi.org/10.35508/jbk.v4i2.18979

Paramita, I. G. A. P. D., & Setyono, E. Y. (2024). The effectiveness of the problem-based learning model and the problem-solving model on student learning outcomes in Bali state polytechnic. *Proceedings of The International Conference on Sustainable Green Tourism Applied Science* (pp. 838–845). Netherlands: Atlantis Press. https://doi.org/10.2991/978-94-6463-622-2_92

Pradani, A. Y., & Supardi, U. S. (2023). Pengaruh model problem based learning (PBL) terhadap keterampilan berpikir kritis siswa pada materi reaksi redoks kelas X SMA Darunnajah Jakarta. *Educational: Jurnal Inovasi Pendidikan dan Pengajaran, 3*(4), 294–302. https://doi.org/10.51878/educational.v3i4.2581

Purnawan, E. (2022). Hubungan motivasi, persepsi melalui strategi pembelajaran terhadap prestasi belajar Bahasa Indonesia siswa kelas IX SMP negeri 1 Pagar Alam. DIADIK: *Jurnal Ilmiah Teknologi Pendidikan, 12*(1), 42–52. https://doi.org/10.33369/diadik.v12i1.21348

Safirah, A. D., Nasution, N., & Dewi, U. (2024). Analysis of the development needs of HOTS-based electronic student worksheets with culturally responsive teaching approach in elementary schools. *IJORER: International Journal of Recent Educational Research, 5*(1), 243–256. https://doi.org/10.46245/ijorer.v5i1.533

Sari, S. D. C., Ardi, T., Parameswary, C. S., & Widiastuti, N. L. (2024). Identifying students' understanding levels and sources of misconceptions in acid–base concepts through a five-tier diagnostic test. *EduChemia Jurnal Kimia dan Pendidikan, 10*(1), 163-174. https://dx.doi.org/10.62870/educhemia.v10i1.35563

Sarnoko, S., Asrowi, A., Gunarhadi, G., & Usodo, B. (2024). An analysis of the application of problem based learning (PBL) model in mathematics for Elementary School students. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi, 8*(1), 188-202. https://doi.org/10.22437/jiituj.v8i1.32057

Septaria, K., & Fatharani, A. (2022). Manga versus webtoon: Alternative science learning module based on Dr Stone. *Jurnal Inovasi Pendidikan IPA, 8*(1), 11-22. https://doi.org/10.21831/jipi.v8i1.43389

Septianingsih, R., Yani, I. P., Pramadita, T., Sukma, I., & Komalasari, M. D. (2024). Penerapan model problem based learning dalam pembelajaran tematik sekolah dasar guna meningkatkan keaktifan siswa. *Journal Innovation in Education, 2*(3), 213–221. https://doi.org/10.59841/inoved.v2i3.1471

Sugiyono. (2021). *Metode penelitian kuantitatif, kualitatif dan R&D*. Bandung: Alfabeta.

Widiastuti, R., & Hermanto, H. (2024). Enhancing pedagogical competence in inclusive early childhood education through interactive digital modules: A pre-experimental study. *Golden Age: Jurnal Ilmiah Tumbuh Kembang Anak Usia Dini, 9*(3), 456-474. https://doi.org/10.14421/jga.2024.93-08

Winarti, A., Iriani, R., Butakor, P. K., Meiliawati, R., & Syarpin. (2024). Transcript-Based lesson analysis: The analysis of classroom communication in chemistry implementing case-based and project-based learning. *Indonesian Journal on Learning and Advanced Education (IJOLAE), 6*(1), 1-13. https://doi.org/10.23917/ijolae.v6i1.23160

Zakiyah, S., Suwarma, I. R., & Rusdiana, D. (2024). Constructing assessment for evaluating critical thinking and creative problem-solving skills in the lesson on soundwave. *Jurnal Penelitian Pendidikan IPA, 10*(8), 4614-4622. https://doi.org/10.29303/jppipa.v10i8.8332

Zayrin, A. A., Nupus, H., Maizia, K. K., Marsela, S., Hidayatullah, R., & Harmonedi. (2025). Analisis instrumen penelitian pendidikan (uji validitas dan reliabilitas instrumen penelitian). *QOSIM: Jurnal Pendidikan, Sosial & Humaniora, 3*(2), 780-789. https://doi.org/10.61104/jq.v3i2.1070