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Design of PBL-STEM E-Worksheet with Differentiated Instruction on Basic Chemical Laws to Improve Learning

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ABSTRAK

Kurikulum merdeka memiliki metode pembelajaran problem-based learning (PBL) dan pendekatan Science, Technologi, Engineering dan Mathematics (STEM) yang terbukti efektif meningkatkan kualitas pendidikan. Namun PBL-STEM dalam pembelajaran kimia materi hukum-hukum dasar kimia belum diterapkan secara optimal. Tujuan penelitian menganalisis kelayakan, keefektifan, serta tanggapan peserta didik terhadap penggunaan E-LKPD. Metode menggunakan jenis Research and Development (R & D) dan model 4D meliputi Define, Design, Develop, Disseminate. Subjek penelitian sejumlah 33 peserta didik kelas X SMA N 3 Semarang. Teknik analisis meliputi kelayakan, keefektifan dan respon peserta didik. Hasil penelitian produk E-LKPD PBL-STEM berkategori valid oleh ahli materi dan berkategori valid oleh ahli media sehingga produk dinyatakan layak untuk digunakan. Keefektifan penggunaan E-LKPD memperoleh rerata N-gain pada kategori cukup. Kenaikan nilai N-Gain peserta didik diketahui jika setiap kelompok belajar menunjukkan kenaikan nilai secara signifikan pada pretest ke postest. Hal ini membuktikan jika penerapan E-LKPD PBL-STEM terintegrasi pembelajaran diferensiasi dikategorikan baik karena dapat meningkatkan hasil belajar peserta didik, didukung juga oleh tanggapan positif dari peserta didik ketika penerapan E-LKPD dilakukan dalam pelajaran di kelas.

ABSTRACT

The "Merdeka" curriculum has a problem-based learning (PBL) method and a Science, Technology, Engineering and Mathematics (STEM) approach that has proven effective in improving the quality of education. However, PBL-STEM in learning chemistry material on the basic laws of chemistry has not been applied optimally. The purpose of the study was to analyze the feasibility, effectiveness, and students' responses to the use of E-Worksheets. The method uses the type of Research and Development (R & D) and the 4D model includes Define, Design, Develop, Disseminate. The research subjects were 33 students of class X SMA N 3 Semarang. Analysis techniques include feasibility, effectiveness and learner response. The results of the PBL-STEM E-Worksheet product research are categorized as valid by material experts and categorized as valid by media experts so that the product is declared suitable for use. The effectiveness of using E-Worksheet obtained the average N-gain in the moderate category. The increase in the N-Gain value of students is known if each study group shows a significant increase in scores from pretest to posttest. This proves that the application of PBL-STEM worksheets integrated with differentiated learning is categorized as good because it can improve the learning outcomes of students, also supported by positive responses from students when the application of worksheets is carried out in classroom lessons.

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INTRODUCTION

The dynamic and ever-changing education system has become a critical issue within Indonesia's education sector. This concern is also stated in Article 35, Paragraph (1) of Government Regulation No. 57 of 2021 concerning National Education Standards (Peraturan Pemerintah Republik Indonesia Nomor 57 Tahun 2021 tentang Standar Nasional Pendidikan), which mandates the development of a diverse curriculum based on the characteristics of regions, educational institutions, and students (Wahyuningsari et al*.,* 2022). The curriculum developed by the Indonesian government in 2021 has reached the stage of implementing the Merdeka Curriculum (Dani & Nurlizawati, 2023). The Merdeka Curriculum incorporates instructional methods such as Problem-Based Learning (PBL) and the Science, Technology, Engineering, and Mathematics (STEM) approach, which have been extensively examined and published in studies by researchers such as (Utaminingsih & Mahanita, 2024). The PBL-STEM instructional method is also aligned with the objectives of the Merdeka Curriculum, which emphasizes the development of students' creative thinking skills and active participation in the learning process. Furthermore, the Merdeka Curriculum adopts a student-centered learning principle by promoting the concept of Merdeka Belajar or "Freedom to Learn" (Cholilah et al*.,* 2023). The learning process within the Merdeka Curriculum requires the implementation of an instructional approach that addresses students' individual needs, commonly known as the differentiation approach (Sutrianto & Asyhar, 2023).

Differentiated instruction is recognized as a learning approach in which teachers make adjustments based on students' interests, learning styles, and readiness to engage in independent learning (Taylor, 2009; Lestari et al., 2025). This indicates that the implementation of differentiated instruction places great emphasis on addressing students' individual needs, including understanding their strengths and weaknesses in the learning process (Nawang Sari et al*.,* 2022).

To support and enhance the learning process, it is essential to provide appropriate teaching materials, learning media, and instructional models that meet students' needs (Haryani et al*.,* 2021). A sustainable instructional model that effectively addresses students' learning difficulties within the context of differentiated instruction is the Problem-Based Learning (PBL) model (Atikah et. al., 2024). In addition, this instructional model requires active learning by presenting real-world problems that are aligned with the four key aspects of STEM, namely the application of science, technology, engineering, and mathematics in authentic contexts (Khairiyah, 2019).

One of the literature findings that support the design of the E-Worksheet for the topic of fundamental chemical laws in this proposal is presented by Monica et. al., (2023), who stated that the development of a PBL-based E-Worksheet offers significant benefits. The PBL model, which is inherently challenging and stimulates curiosity, enables students to experience the benefits of solving problems, increases their interest in learning fundamental chemical laws, and encourages active participation in the learning process.

The study conducted by Zuliatin et al., (2022) concluded that students can engage in more active and non-monotonous learning in the classroom by utilizing practical learning media through the Kvisoft Flipbook Maker application, which serves as an electronic form of the worksheet (E-Worksheet). This media also assists teachers in delivering the topic of atomic structure using the STEM approach, which often requires tangible learning media to help students apply their understanding of atomic structure.

Chemistry learning at SMA Negeri 3 Semarang, based on interviews with teachers and students, revealed that students' learning outcomes on the topic of Fundamental Chemical Laws are still largely below the Minimum Mastery Criteria (KKM). The KKM set for this subject is 75; however, out of 34 students in the class, 14 students have not yet achieved mastery. One of the factors suspected to contribute to these low learning outcomes is the use of inappropriate instructional models. The learning process in the classroom is still dominated by lecture and discussion methods, although laboratory activities are occasionally conducted. In addition, observations indicate that no electronic worksheet (E-Worksheet) is currently being utilized by students, particularly an E-Worksheet designed by integrating the Problem-Based Learning (PBL) model with a STEM approach to support the implementation of differentiated instruction in chemistry learning.

It can be concluded that there is a need for alternative learning media, such as an E-Worksheet, developed with innovative instructional models that incorporate technological aspects to support the learning process of students. This has encouraged researchers to develop teaching materials in the form of an E-Worksheet that covers the topic of Fundamental Chemical Laws by integrating the PBL-STEM approach within the context of chemistry learning. The E-Worksheet is designed in an electronic format and structured to accommodate different levels of students' abilities in understanding the topic of Fundamental Chemical Laws.

METHODS

This study employs a quantitative approach with a Research and Development (R&D) design using the Four-D (4D) model, which consists of four stages: Define, Design, Develop, and Disseminate. The research follows the 4D model; however, the dissemination stage is conducted through the publication of scientific articles. The stages include the definition phase (Define), the design phase (Design), the development phase (Develop), and the dissemination phase (Disseminate). The main advantage of the 4D model lies in the Disseminate stage, which allows the developed product to be tested on a broader scale before full implementation. This is particularly important in development research, such as the development of worksheets, learning modules, or interactive media, which require trials and validation before being widely used (Thiagarajan et al., 1974, hlm. 12). The procedural framework implemented by the researcher for this study is illustrated in the diagram shown in Figure 1.

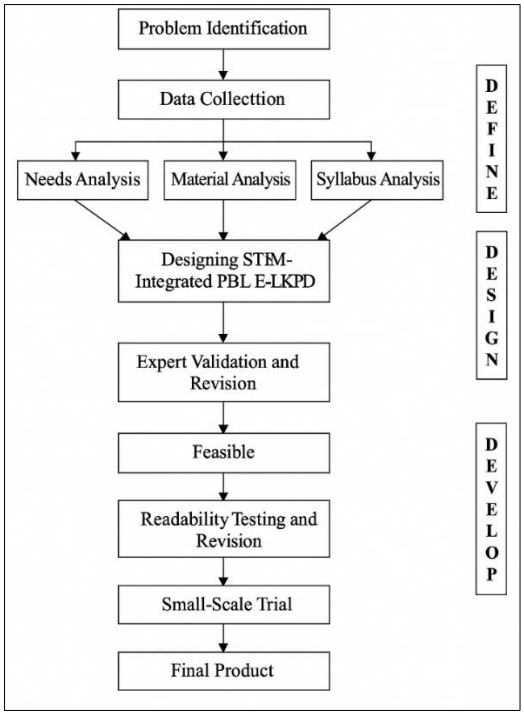

Figure 1. Research Procedure

The sample used in this study for the small-scale trial was obtained through a questionnaire that was distributed to the students (Sugiyono, 2019). This aims to evaluate the E-Worksheet as well as the pretest and posttest, which were administered to Class 11 MIPA 1 consisting of 26 students. The E-Worksheet that has been tested will then be assessed and revised to ensure its feasibility for the next stage of the research, which will be conducted in Class 10 MIPA 8. Several small-scale tests were carried out during this phase.

The trial involved 26 students from Grade XII of SMA Negeri 3 Semarang who had previously studied the topic of Fundamental Chemical Laws. The students were divided into three groups based on their learning readiness, which was determined by their summative assessment scores: beginner, intermediate, and advanced groups. The students' learning outcomes during the use of the developed E-Worksheet were analyzed. The validity of the test instruments was ensured through item validation, reliability testing, item difficulty index, and item discrimination index. Meanwhile, non-test instruments, such as questionnaires, were validated through expert review and readability tests.

RESULT AND DISCUSSION

The purpose of this study is to determine the feasibility and effectiveness of the STEM-integrated Problem-Based Learning (PBL) E-Worksheet within the context of differentiated instruction for the topic of Fundamental Chemical Laws. This study also aims to examine the improvement in students' learning outcomes as measured by the N-Gain, categorized based on students' learning groups. The feasibility of

the developed E-Worksheet was assessed through the Four-D (4D) development model. The first stage, Define, involved analyzing the needs of both students and teachers, as well as identifying the relevant curriculum content and learning materials. This stage was intended to ensure that the development of the STEM-integrated PBL E-Worksheet for learning the Fundamental Chemical Laws would address existing learning needs and contribute positively to students' learning outcomes.

The second stage, Design, focused on creating an effective, engaging, and structured worksheet to assist students in understanding the learning material. At this stage, a draft of the E-Worksheet was prepared, consisting of three main sections: introduction, content, and conclusion. Before finalizing the draft, important considerations included selecting the appropriate format and learning media to be used. The third stage, Develop, aimed to implement the concept into an efficient and interactive learning medium. At this stage, the draft of the E-Worksheet was refined to integrate the PBL-STEM approach, consisting of three learning activities for each student group, group-specific worksheets, and relevant learning content. The final stage, Disseminate, was carried out by publishing a scientific article to complement the description of the developed E-Worksheet, making it accessible as a reference for other educators or researchers.

The feasibility of the developed product was evaluated by two chemistry lecturers and one high school chemistry teacher through expert validation and a small-scale trial. The expert validation included a content validation process, with the results presented in Table 1.

Table 1. Expert Validation of Content

Aspect Content Feasibility	**Percentage**		**Mean**	**Category**
	Expert 1	**Expert 2**		
Presentation Feasibility	97,20%	88,89%	93,04%	Highly Valid
Language Feasibility	94,40%	86,11%	90,25%	Highly Valid
STEM Approach	93,75%	90,62%%	93,00%	Highly Valid
Average	87,50%	100%	93,75%	Highly Valid
All Aspect			92,51%	Highly Valid

The analysis results show that the average score across all assessed aspects reached 92.51%. This percentage indicates that the developed E-Worksheet is categorized as highly valid and is considered feasible for use based on the evaluation by content experts. These feasibility results are consistent with the findings of Winarti et al., (2024), in which the overall validation score for a PBL-based E-Worksheet on acid-base material reached 85.2%, indicating a valid category. Furthermore, the results of the media expert validation, including the obtained percentage scores, are presented in Table 2.

Based on this analysis, it can be concluded that the developed E-Worksheet is feasible for use, as the overall score for all aspects falls within the highly valid category, indicating the feasibility of the E-Worksheet according to the media expert's assessment. These findings are consistent with previous

research that developed a PBL-based E-Worksheet on the topic of Systems of Linear Equations in Three Variables (SPLTV), which obtained a validity score of 85.8% from content and media experts, indicating that the product was categorized as valid (Dwi Aryanti & Yunita, 2024).

Table 2. Media Expert Validation

Aspect	Percentage		Mean	Category
	Expert 1	Expert 2		
Presentation	97,20%	91,60%	94,00%	Highly Valid
Consistency	94,40%	100%	97,00%	Highly Valid
Graphics	93,75%	93,75%%	93,00%	Highly Valid
STEM Approach	87,50%	75,00%	81,00%	Highly Valid
Average			91,25%	Highly Valid

Furthermore, a small-scale trial was conducted through the distribution of questionnaires to students. This aimed to evaluate the E-Worksheet as well as the pretest and posttest, which were administered to Class 11 MIPA 1, consisting of 26 students. The tested E-Worksheet was then assessed and revised to ensure its suitability for the next stage of the research, which will be carried out in Class 10 MIPA 8. The results of the small-scale trial are presented in Table 3.

Table 3. Results of Small-Scale Trial Implementation

No.	Statement	Percentage	Category
1	The learning steps using the differentiated STEM-integrated PBL E-Worksheet on the topic of Fundamental Chemical Laws are easy to implement in classroom learning.	100%	Very Good
2	Students carry out the learning activities provided in the E-Worksheet well.	90%	Good
3	Students are able to operate the E-Worksheet without significant difficulties.	100%	Very Good
4	Students ask questions if there is something they do not understand from the E-Worksheet.	100%	Very Good
5	Students actively participate in every learning activity.	85%	Good
6	The time allocation for learning using the E-Worksheet is sufficient.	80%	Good
7	The time allocation for concluding the lesson is sufficient.	95%	Very Good
8	The time allocation for learning activities is sufficient.	85%	Good
9	The process of analysis and problem-solving can be carried out during learning activities.	100%	Very Good
10	The predetermined learning objectives can be achieved by the students.	100%	Very Good
	Average	93.5%	Very Good

The quality of the test instruments used to measure students' problem-solving abilities was validated by chemistry lecturers from Universitas Negeri Semarang and a chemistry teacher for Grade X at SMA Negeri 3 Semarang prior to their use in the trial. The percentage results of the expert validation for each assessed aspect are presented in Table 4.

Table 4. Results of Test Instrument Validation

Aspect	Percentage		Mean	Category
	Expert 1	Expert 2		
Construction	91,60%	91,60%	91,60%	Highly Feasible
Language	100%	91,60%	95,80%	Highly Feasible
Content	83.30%	91,60%	87,45%	Highly Feasible
Average			91,67%	Highly Feasible

The analysis results show that the average score across all assessed aspects reached 91.67%, indicating that the developed test instrument is feasible for use and falls into the highly valid category. The average score obtained is supported by the findings of Prawita et al., (2019), who stated that expert validation provides an objective assessment of the feasibility of test items and ensures that the instrument is effective in measuring students' competencies in chemistry.

The validity and reliability of the posttest items were tested using the Anates application to ensure that the items met the criteria for validity and reliability before being implemented in the trial phase. The validity results of the posttest items are presented in Table 5.

Table 5. Posttest Item Validity

Test Item	r_{hitung}	r_{kritis}	Description	Difficult Index	Discrimination Index (%)
1	0,584	0,377	Valid	Easy	78,57
2	0,756	0,377	Highly Valid	Moderate	114,29
3	0,612	0,377	Valid	Easy	71,43
4	0,693	0,377	Valid	Moderate	90,00
5	0,744	0,377	Highly Valid	Easy	78,57
6	0,608	0,377	Valid	Moderate	119,64
7	0,585	0,377	Valid	Easy	59,52
8	0,377	0,377	-	Very Easy	8,93
9	0,590	0,377	Valid	Easy	100,00
10	0,224	0,377	-	Moderate	14,29

The data analysis results showed an average score of 60.12 with a standard deviation of 11.71, indicating a significant variation in student scores. The correlation between variables X and Y was 0.54, demonstrating a strong positive relationship, suggesting that the test has good predictive ability. The test items are considered valid if the point-biserial correlation coefficient (Ypbi) is greater than or equal to the critical r value from the table. In this study, the Ypbi values for the test items, as shown in Table 4.13, ranged from 0.584 to 7.56, indicating high validity. These findings are consistent with the study by Rizky

A., Amsul Al M. Z., et al., (2019), which also reported a high level of test validity.

The difficulty index results showed that five items (items 1, 3, 5, 7, and 9) were categorized as easy, while four items (items 2, 4, 6, and 8) were categorized as moderate. These results are in line with the findings of Rizky A., Amsul Al M. Z., et al., (2019), who stated that good-quality test items fall within categories that are neither too easy nor too difficult. The discrimination index analysis revealed that eight items (items 1 to 7 and item 9) fell into the high discrimination category, while two items (items 8 and 10) were categorized as low discrimination. Furthermore, the test reliability was calculated at 0.70, indicating good measurement consistency (Aiken, 1980).

The effectiveness of the product was determined through the assessment of students' problem-solving abilities, which were tested during the large-scale implementation phase involving 25 students from Grade X at SMA Negeri 3 Semarang. The learning process utilized a differentiated E-Worksheet, designed based on a mapping of students' learning needs, which included differentiation in terms of process, content, and product. The pretest and posttest were developed to measure and improve students' problem-solving abilities. The tests consisted of essay-type questions, with a total of 10 items used as both pretest and posttest instruments. The tests were administered to 33 students from Grade X at SMA Negeri 3 Semarang. The results of the pretest and posttest are presented in Figure 2.

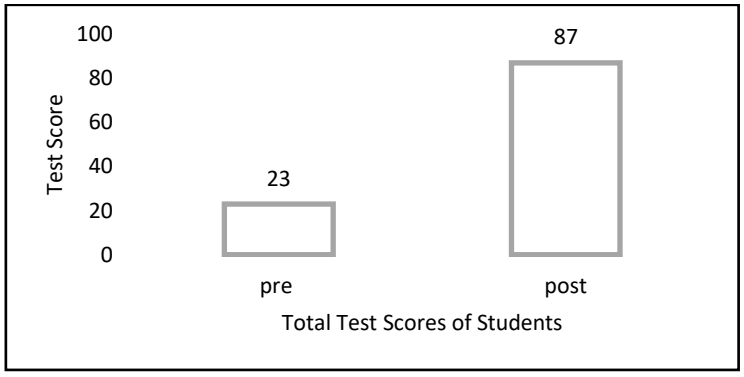

Figure 2. Graph of Average Pretest and Posttest Scores

The average pretest score of the students was 23, while the average posttest score increased to 87. This improvement indicates a significant development in students' problem-solving abilities after using the E-Worksheet during the learning process. However, to accurately determine the extent of this improvement, further analysis is required using the N-Gain test to more precisely measure the effectiveness of the developed E-Worksheet. The N-Gain test was conducted to analyze the differences between the pretest and posttest scores and to determine whether a significant improvement occurred after the learning process. The results of the N-Gain analysis are presented in Table 6.

Table 6. N-Gain Results for Cognitive Aspect

Learning Group	Percentage	Category
Beginner	53%	Enough
Intermediate	55%	Enough
Advanced	61%	Effective
Average N-Gain	56%	Effective

According to Investopedia (2024), the Gain percentage is calculated by multiplying the Gain ratio by 100 to obtain a percentage value that is more intuitively understandable. The highest N-Gain was obtained in the advanced group, with a percentage of 61%, which falls under the effective category. This is because students in the advanced learning group already had a better understanding of the subject matter, as reflected in their posttest performance, while their pretest scores were considered fairly good, although not reaching around 80.

The N-Gain for the beginner group was 53%, and although this group and the intermediate group were both categorized as moderately effective, their scores were still lower compared to those of the advanced group. However, a closer examination of the beginner group's scores showed an improvement from pretest to posttest, albeit not significantly high, indicating that students in this group still require teacher guidance during the learning process.

The increase in N-Gain for each group was reflected in the N-Gain test, which showed an overall average N-Gain of 0.56, indicating an improvement in learning outcomes that falls within the effective category. This study also revealed that the number of students in each learning group was not evenly distributed: the beginner group consisted of one group with six students, the intermediate group consisted of two groups with six students each, and the advanced group consisted of three groups with five students each. The increase in Gain values for each group is illustrated in Figure 3.

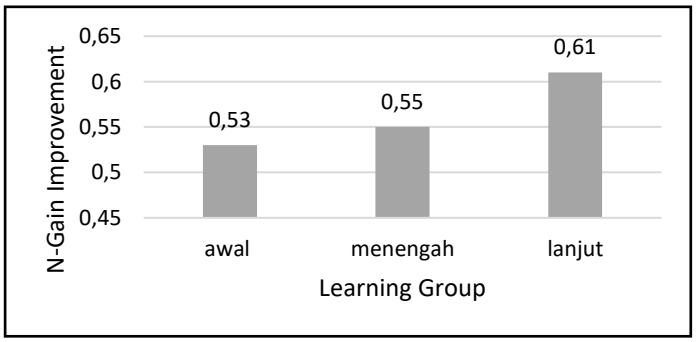

Figure 3. N-Gain Improvement for Each Learning Group

The research data showed that the advanced learning group, consisting of high-ability students, experienced a greater N-Gain improvement compared to the beginner group with lower abilities. This can be attributed to their stronger cognitive abilities, higher learning motivation, and more effective

learning strategies, enabling them to understand the material more quickly and respond better to the applied learning methods (Pratama, 2021; UAD eprints, 2020). Although the absolute room for improvement was smaller, the N-Gain remained high due to a significant relative increase (Hake, 1998). Empirical studies also support the finding that interactive and challenging learning methods are more effective in improving learning outcomes for high-ability students (Jurnal Riset Pendidikan Dasar dan Karakter, 2021). Therefore, it can be concluded that both the applied learning methods and student characteristics play a significant role in determining the magnitude of learning outcome improvement.

CONCLUSION

The results of this study, based on the structured process to address the research problems, indicate that the PBL-based E-Worksheet integrated with STEM in differentiated learning on the topic of Fundamental Chemical Laws has met the validity and feasibility criteria for use. The content expert validation results indicated a valid category, while the media expert validation results fell under the highly valid category. Furthermore, the implementation test results were categorized as very good, and the readability test results were also categorized as very good. The PBL-based, STEM-integrated E-Worksheet for differentiated learning on Fundamental Chemical Laws proved to be moderately effective in improving students' learning outcomes. In addition, each learning group showed significant improvement. The increase in students' N-Gain scores also demonstrated that all learning groups, from beginner to advanced, experienced a significant improvement from pretest to posttest.

REFERENCE

Aiken, L. R. (1980). Content Validity And Reliability Of Single Items Or Questionnaires. Educational And Psychological Measurement, 40(4), 955–959. https://Doi.Org/10.1177/001316448004000419

Atikah, I., Fauzi, M. A. R., & Firmansyah, R. (2023). Penerapan Strategi Diferensiasi Konten Dan Proses Pada Gaya Belajar Berbasis Model Problem Based Learning. Pubmedia Jurnal Penelitian Tindakan Kelas Indonesia, 1(2), 11. Https://Doi.Org/10.47134/Ptk.V1i2.57

Cholilah, M., Gratia Putri Tatuwo, A., Prima Rosdiana, S., & Noor Fatirul, A. (2023). Pengembangan Kurikulum Merdeka Dalam Satuan Pendidikan Serta Implementasi Kurikulum Merdeka Pada Pembelajaran Abad 21. *Sankskara Pendidikan Dan Pengajaran*, *01*(02), 57–66. Https://Doi.Org/10.58812/Spp.V1.I02

Dani, A. R., & Nurlizawati, N. (2023). Adaptasi Guru Sosiologi Sekolah Penggerak Di Kota Padang Terhadap Kurikulum Merdeka. Naradidik: Journal Of Education And Pedagogy, 2(2), 140–147. Https://Doi.Org/10.24036/Nara.V2i2.100

Dwi Aryanti, N., & Yunita, A. (2024). Pengembangan E-Lkpd Berbasis Problem Based Learning Pada Materi Spltv DiFase E.7(3). Https://Doi.Org/10.31764/Justek.Vxiy.Zzz

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

Haryani, S., Dewi, N. R., Rusilowati, A., Saptono, S., Wiyanto, W., Ridlo, S., ... & Atunnisa, R. (2021). Technological, Pedagogical, Content Knowledge (Tpack) Research Trends: A Systematic Literature Review Of Publications Between 2010-2020. *Journal Of Turkish Science Education*, *18*(4), 589-604

Investopedia. (2024, July 12). How To Calculate the Percentage Gain or Loss on an Investment. Retrieved from https://www.investopedia.com/ask/answers/how-do-you-calculate-percentage-gain-or-loss-investment/

Jurnal Riset Pendidikan Dasar dan Karakter. (2021). Efektivitas metode pembelajaran interaktif terhadap hasil belajar peserta didik berkemampuan tinggi. Jurnal Riset Pendidikan Dasar dan Karakter, 3(1), 45–56. https://jurnal.stkippersada.ac.id/jurnal/index.php/JPE/article/download/2068/1550

Khairiyah, N. (2019). Pendekatan Science, Technology, Engineering, And Mathematics (Stem). Medan: Spasi Media.

Lestari, D., Oktiani, R., Lutfianasari, U., & Imaduddin, M. (2025). Chemistry Teachers' Perspectives on the Implementation of Interdisciplinary Science Projects in Vocational Schools: Challenges and Strategic Solutions. JTK (Jurnal Tadris Kimiya), 10(1), 76–91. https://doi.org/10.15575/jtk.v10i1.37830.

Nawang Sari, R., Riya Anggraini, T., Komering Ulu, O., & Pgri Bandar Lampung, S. (2022). Pembelajaran Berdiferensiasi Dengan Multimedia Interaktif Meningkatkan Hasil Belajar Kimia. Jurnal Pengajaran Dan Riset, 02(02), 139.

Monica, I., Nurhamidah, & Elvinawati. (2023). Pengembangan E-Lkpd Berbasis Problem Based Learning Pada Materi Hukum-Hukum-Hukum Dasar Kimia. *Jurnal Pendidikan Dan Ilmu Kimia*, *7*(1), 33–43.

Pratama, P. (2021). Peningkatan kemampuan kolaborasi pada pembelajaran berbasis masalah dengan pendekatan TaRL. COLLASE - Jurnal Mahasiswa IKIP Siliwangi, 5(2), 1218-1228. Diakses dari https://journal.ikipsiliwangi.ac.id/index.php/collase/article/view/9962/2960Prawita, W., Prayitno, B. A., & Sugiyarto. (2019). Effectiveness Of A Generative Learning-Based Biology Module To Improve The Analytical Thinking Skills Of The Students With High And Low Reading Motivation. International Journal Of Instruction, 12(1), 1459–1476. Https://Doi.Org/10.29333/Iji.2019.12193a

Rizky A., Amsul Al M. Z., et al. (2019). Penerapan Aplikasi Anates Dengan Bentuk Soal Pilihan Ganda Di Sd Muhammadiyah Gendeng. Jurnal Elementary, 2(1). Https://Doi.Org/10.31764/Elementary.V1i2.549

Sugiyono. (2017). Metode Penelitian Pendidikan (Kuantitatif, Kualitatif, Kombinasi, R&D Dan Penelitian Pendidikan). Alfabeta

Sutrianto, A., & Asyhar, R. (2023). Penerapan Pembelajaran Diferensiasi Untuk Meningkatkan Hasil Belajarmatematika Siswa Kelas Xii Sma Xaverius 1 Jambi Tahun Pelajaran2023/2024 (Implementasi Kurikulum Merdeka). Jounal On Education, 06(01), 10259–10264. Https://Jonedu.Org/Index.Php/Joe/Article/View/4721

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children. Bloomington, IN: Indiana University, Center for Innovation in Teaching the Handicapped.

Utaminingsih, S., & Mahanita, B. (2024). Manajemen Pembelajaran Stem-Probelem Based Learning Berbasis Lesson Study Dalam Kurikulum Merdeka. Jurnal Ilmiah Kependidikan, 7(1), 65–74. Http://Jurnal.Umk.Ac.Id/Index.Php/Pendas/Index

Winarti, Nurfajriani, & Simorangkir, M. (2024). Pengembangan E-Lkpd Kimia Berbasis Problem Based Learning Pada Materi Laju Reaksi Sesuai Kurikulum Merdeka. Didaktika: Jurnal Kependidikan, 13(2), 2241–2251.

Zuliatin, Q., Fatayah, F., Ika, D., & Yuliana, F. (2022). Pengembangan E-Lkpd Berbasis Stem (Science, Technology, Engineering, And Mathematic) Pada Materi Struktur Atom Development Of Stem-Based E-Lkpd (Science, Technology, Engineering, And Mathematic) On Materials Atomic Structure. In Unesa Journal Of Chemical Education (Vol. 11, Issue 3)

Taylor, R. (2009). Assessment Of Exceptional Students, Educational And Psychological Procedures. New Jersey: Pearson.