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Universitas Sanata Dharma
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# DEVELOPING AN ELECTRONIC STUDENT WORKSHEET WITH PROCESS DIFFERENTIATION FOR THE CHEMICAL KINETICS TOPIC

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**Abstract**
This study develops and evaluates an electronic student worksheet with process differentiation for the topic of chemical kinetics. It is motivated by students' difficulties in understanding the complex concepts of chemical kinetics and the persistence of conventional teaching methods. The worksheet was developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) and tested on 21 eleventh-grade high school students. Data were analyzed through N-Gain calculations and response percentages. The results indicate that the worksheet meets the feasibility criteria. Expert validation showed that the worksheet is highly feasible, with average scores of 92% for content, 88.8% for activities, 95% for appearance and visuals, and 93.3% for language, resulting in an overall average of 92.4%. Practicality was confirmed by students' high positive responses, who strongly agreed that the worksheet was engaging and easy to use. Effectiveness was demonstrated through N-Gain analysis, with improvements in learning outcomes for auditory (0.64), visual (0.69), and kinesthetic (0.68) learners, all categorized as "Medium." Thus, the student worksheet is proven effective, practical, and feasible for improving learning outcomes in chemical kinetics, offering an innovative alternative learning resource that accommodates diverse student characteristics.

**Keywords:** chemical kinetics, electronic student worksheets, process differentiation

## Introduction

Chemistry is often perceived as a difficult subject for students (Priliyanti et al., 2021). Many chemistry concepts, including chemical kinetics, involve phenomena that cannot be directly observed, which leads to low student interest in learning the topic (Siregar et al., 2024). The topic of chemical kinetics requires reasoning skills and often causes difficulties in understanding. Chemistry learning in schools tends to be dominated by lecture-based teaching and assignments, which do not sufficiently encourage students to actively construct their own understanding (Sariati et al., 2020). Monotonous activities and conventional learning strategies that focus too much on classroom instruction without considering students' needs or interests may lead to low learning outcomes (Laia et al., 2022).

Each student differs in understanding, prior knowledge, and learning pace; some require more support, while others are ready for greater challenges. Additionally, students' learning interests vary: those interested in a topic are more

motivated to study deeply, while those less interested need different approaches to spark engagement (Diastono et al., 2018). Learning style refers to how students receive and process new information. There are three types of learning styles: visual (learning through observation, such as diagrams and videos), auditory (learning through listening, such as discussions and lectures), and kinesthetic (learning through physical and hands-on activities, such as experiments) (Sudiana et al., 2019). Referring to the three elements: content, process, and product, differentiation is expected to optimize each student's learning potential, increase engagement and motivation, and create an inclusive learning environment (Herwina, 2021).

Learning style refers to the approach chosen by students in receiving and processing new information. It is categorized into visual learning style (facilitating learning through observation, such as diagrams and videos), auditory learning style (enabling learning through listening, such as discussions or lectures), and kinesthetic learning style (facilitating learning through physical or hands-on activities, such as experiments) (Sudiana et al., 2019). Understanding these learning styles is crucial in process differentiation, a teaching strategy in which teachers adapt instructional methods, tools, and learning activities to match each student's learning needs and preferences, enabling them to learn in the most effective way (Aprima & Sari, 2022).

The rapid development of technology has the potential to transform students' learning methods. One innovative teaching material that can be utilized is the Electronic Student Worksheet (ESW). ESW enables more interactive learning as it is equipped with images, videos, and simulations, helping students visualize complex chemical concepts more easily. Furthermore, ESW is easily accessible, allowing students to learn independently, review difficult materials, and explore topics at their own pace (Sari & Purwaningsih, 2019).

ESW is designed systematically and interactively, often equipped with various multimedia features such as animations, images, videos, and navigation tools that enable direct user interaction with the program. As a digital learning material, ESW not only provides textual content but also includes visual and audio elements that enrich the learning experience (Budiasih et al., 2022). The use of ESW encourages students to be more actively involved in the learning process, such as by watching educational videos, reading materials, conducting simulated experiments, engaging in discussions, and answering embedded questions. Thus, ESW serves as an engaging, active, and adaptable learning resource that supports effective learning (Sariani & Suarjana, 2022).

In implementing the ESW with process differentiation, this can be done by providing various learning activities or using media tailored to the needs of each individual. By accommodating the diversity of learning needs, process differentiation can optimize each student's potential, enhance understanding, and create more effective learning (Azura et al., 2019). Process differentiation allows educators to vary how students learn and demonstrate understanding. In the implementation of ESW and Discovery Learning, this can be achieved by offering a range of activities or media adapted to individual needs. Thus, process differentiation can optimize potential, enhance comprehension, and create effective learning experiences for all students. These issues and phenomena underpin this research, which aims to develop an ESW using the Discovery Learning Model based on Process Differentiation in the topic of Chemical Kinetics. This study is

expected to produce an ESW that is valid, practical, and effective in improving students' understanding of chemical kinetics.

## Method

This study employed a Research and Development (R&D) approach using the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Yahya et al., 2024). In the analysis stage, researchers identified students' needs, characteristics, and learning difficulties related to chemical kinetics through interviews with chemistry teachers and students from grades XI–XII. The design stage involved creating instructional materials based on the analysis results. During the development stage, the product was constructed, validated by experts, and revised according to feedback. The implementation stage consisted of a limited trial with 21 grade XI students at Pangudi Luhur St. Louis IX High School implementing the Merdeka Curriculum. The evaluation phase assessed the product's validity, effectiveness, and practicality (Hasniyah & Muchtar, 2021).

## Findings and Discussion

The ADDIE development model involves several stages: analysis, design, development, implementation, and evaluation. The first stage consists of analyzing student and teacher needs, analyzing materials, and learning media. This analysis aims to determine the needs and circumstances of students in schools implementing the Merdeka Curriculum.

Based on the results of the observation analysis, difficulties arose for the teachers when **preparing learning materials and media,** which could lead to **misconceptions.** In addition to causing misconceptions, teachers also need time to prepare materials and learning media integrated with a learning model. For students, **chemical kinetics material can be difficult and requires engaging learning methods**. Based on the interview results with the chemistry teacher at Pangudi Luhur St. Louis IX Senior High School, students felt that the learning provided tended to be **overly reliant on the textbook, making them bored and not meeting their learning needs in line with their** interests. Thus, based on the analysis with the chemistry teacher at Pangudi Luhur St. Louis IX Senior High School, it is known that the use of **ESW is highly necessary** for assigning tasks to students, as well as a means of student assessment.

After completing the analysis phase, the next step is the design phase. The design phase is the stage of product development, which begins with the creation of a storyboard, the design of the media, and assessment. The creation of the storyboard and the chemistry content is designed using Microsoft Word. The chemistry content, which consists of the learning stages or learning scheme, begins with the creation of learning activities adapted to the stages of discovery learning and descriptions of each learning activity. The media design involves the use of audio, video, images, and interactive simulations included in the ESW, with the design being created by Canva. The product design is presented in Figure 1. The assessment design is carried out by creating a blueprint for the test items, followed by writing the questions on Quizizz so that they can be accessed by students via a link included in the ESW. Thus, the final media product is an ESW provided to

students in the form of a Google Sites link that was developed to cover chemical kinetics material with process differentiation for Phase F (Grade XI).


Figure 1. The Product Design for Auditory, Visual, and Kinesthetic Learning Style

The next step, which is the development stage, includes the development of the ESW content, the development of competency test questions, and a feasibility test by validators, as well as the results of the feasibility test. The ESW content development is adapted to the auditory, visual, and kinesthetic learning styles of the students. The development of competency test questions is carried out according to the blueprint of the item set, created in the form of multiple-choice questions, and used for the pretest and posttest. The product feasibility test is conducted by 3 validators, while the feasibility test of the competency questions and the product use questionnaire is conducted by 2 validators. Comments and suggestions are provided to serve as a guide for product refinement so that the product can be declared suitable for trial. According to Akker et al. (2006), a development product must meet the criteria of being valid, practical, and effective. Akker et al. (2006) further explain that the product must meet the validity criteria to obtain a quality product. Furthermore, the development product must satisfy the practicality criterion because a development product is considered good quality if the product users assess the product as easy to use and applicable. If these are met, the development product must also fulfill the effectiveness criterion, which indicates that the developed product has successfully achieved the expected goals.

Table 1. Score of Product Quality Assessment

| Assessment of product quality | Validity (%) | Category |
|---|---|---|
| Content | 92.5 | Very Valid |
| Learning Activity | 88.8 | Very Valid |
| Illustration and Design | 95 | Very Valid |
| Language feasibility | 93.3 | Very Valid |
| Average | 92.4 | Very Valid |

Based on Table 1, four aspects of validation were conducted on the ESW. Based on the product validation results by three validators, four validation aspects of the ESW product have a validity level of "Very Valid". Thus, the product is declared worthy of being tested; however, with suggestions provided by the three validators. After the product is validated, it is then implemented or tested on students. The practicality of the developed product is identified by the results of the student response questionnaire, and the effectiveness of the developed product is identified by the results of the comparison of pre-test and post-test scores by calculating N-Gain.

Table 2. Results of the Analysis of the Practicality Level of the ESW Product

| Assessment aspects | Total score | Maximum score | Level of agreement |
|---|---|---|---|
| Learning media | 695 | 840 | Strongly Agree |
| Material | 275 | 315 | Strongly Agree |
| Benefits | 241 | 315 | Agree |
| Total | 1211 | 1470 | Strongly Agree |

Based on Table 2, the respondents' responses to the statement items showed that the majority of respondents chose the assessments "Agree" and "Strongly Agree". In the learning media aspect, the average response assessment was "Agree". In the material aspect, the response assessment was "Strongly Agree". In the benefit aspect, the average response assessment was "Agree". The analysis results with the level of respondent agreement "Agree" and "Strongly Agree" strengthen that the objectives to be achieved by the product, with process differentiation in the chemical kinetics material used by students, are easy to use and practical. According to Riyadi et al. (2014), a learning tool is said to be practical if it meets the practicality aspect, namely that the tool developed can be applied. The practicality test stage, carried out by giving a response questionnaire to students, was carried out to determine the ease of use of the product (Andriana & Kartolo, 2022). Thus, the ESW with process differentiation learning in the chemical kinetics material is practical because it meets the learning media aspects, material aspects, and benefit aspects that have been designed by the researcher.

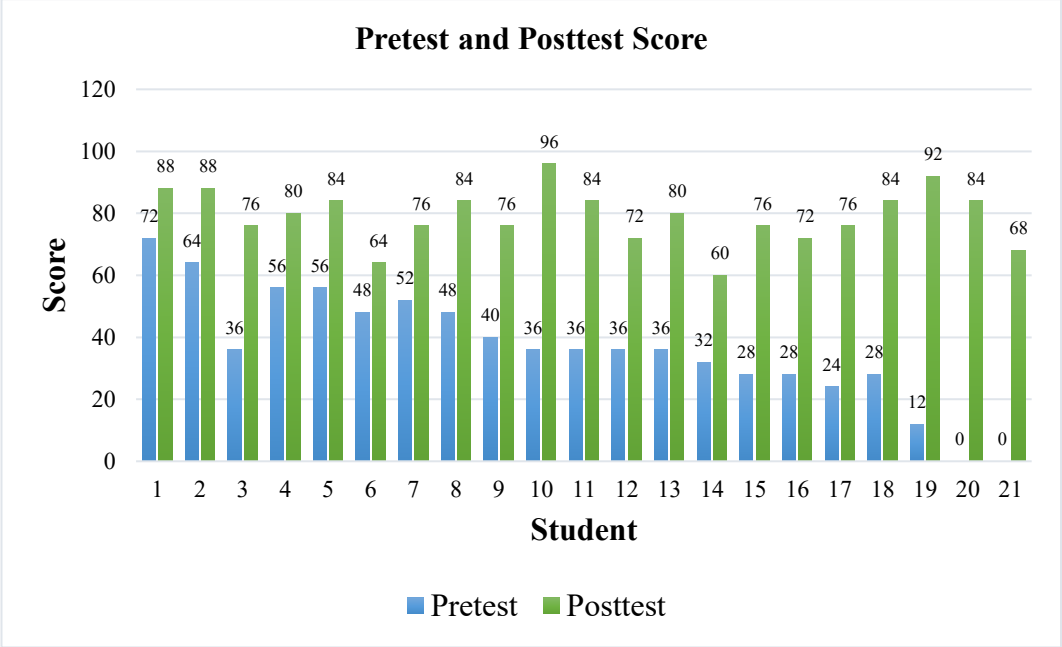


Figure 2. Value Comparison of Pretest and Posttest Scores

Based on Figure 2, the competency test results obtained from the pretest and posttest scores generally showed an increase from PD1 to PD21. Therefore, the increase in scores indicates positive progress or the desired outcome. The next analysis to prove the effectiveness of the competency test was an N-Gain test.

Table 3. Results of the N-Gain Score for Auditory Learning Style

| No | Student | Score | |
|---|---|---|---|
| | | Pretest | Posttest |
| 1. | APD $_1$ | 72 | 88 |
| 2. | APD $_2$ | 64 | 88 |
| 3. | APD $_5$ | 56 | 84 |
| 4. | APD $_9$ | 40 | 76 |
| 5. | APD $_{13}$ | 36 | 80 |
| 6. | APD $_{16}$ | 28 | 72 |
| 7. | APD $_{17}$ | 24 | 76 |
| | Average | 45.71 | 80.57 |
| | N-Gain Score | 0.64 | Moderate |

Based on Table 3, the results of the N-Gain score pretest-posttest on students with auditory learning styles obtained an average N-Gain score of 0.64. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the "moderate" category if $0.3 < g \leq 0.7$.

Table 4. Results of the N-Gain Score for visual learning style

| No | Student | Score | |
|---|---|---|---|
| | | *Pretest* | *Posttest* |
| 1. | VPD $_3$ | 36 | 76 |
| 2. | VPD $_{11}$ | 36 | 84 |
| 3. | VPD $_{12}$ | 36 | 72 |
| 4. | VPD $_{14}$ | 32 | 60 |
| 5. | VPD $_{18}$ | 28 | 84 |
| 6. | VPD $_{19}$ | 12 | 92 |
| | Average | 30 | 78 |
| | *N-Gain Score* | 0.69 | Moderate |

Based on Table 4, the results of the pretest-posttest N-Gain Score test on students with a visual learning style obtained an average N-Gain score of 0.68. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the "moderate" category if $0.3 < g \leq 0.7$.

Table 5. Results of N-Gain Score Calculation for Pretest and Posttest of Kinesthetic Learning Style

| No | Student | Score | |
|---|---|---|---|
| | | *Pretest* | *Posttest* |
| 1. | KPD $_4$ | 56 | 80 |
| 2. | KPD $_6$ | 48 | 64 |
| 3. | KPD $_7$ | 52 | 76 |
| 4. | KPD $_8$ | 48 | 84 |
| 5. | KPD $_{10}$ | 36 | 96 |
| 6. | KPD $_{15}$ | 28 | 76 |
| 7. | KPD $_{20}$ | 0 | 84 |
| 8. | KPD $_{21}$ | 0 | 68 |
| | Average | 33.5 | 78.5 |
| | *N-Gain Score* | 0.68 | Moderate |

Based on Table 5, the results of the pretest-posttest N-Gain test on students with a kinesthetic learning style obtained an average N-Gain score of 0.67. According to Majdi, Subali, & Sugianto (2018), the average N-Gain value is included in the "moderate" category if $0.3 < g \leq 0.7$.

Table 6. Results of the overall N-Gain Score

| No | Student | Score | |
|---|---|---|---|
| | | *Pretest* | *Posttest* |
| 1. | APD $_1$ | 72 | 88 |
| 2. | APD $_2$ | 64 | 88 |
| 3. | VPD $_3$ | 36 | 76 |
| 4. | KPD $_4$ | 56 | 80 |
| 5. | APD $_5$ | 56 | 84 |
| 6. | KPD $_6$ | 48 | 64 |
| 7. | KPD $_7$ | 52 | 76 |

| No | Student | Score | |
|---|---|---|---|
| | | *Pretest* | *Posttest* |
| 8. | KPD $_{8}$ | 48 | 84 |
| 9. | APD $_{9}$ | 40 | 76 |
| 10. | KPD $_{10}$ | 36 | 96 |
| 11. | VPD $_{11}$ | 36 | 84 |
| 12. | VPD $_{12}$ | 36 | 72 |
| 13. | APD $_{13}$ | 36 | 80 |
| 14. | VPD $_{14}$ | 32 | 60 |
| 15. | KPD $_{15}$ | 28 | 76 |
| 16. | APD $_{16}$ | 28 | 72 |
| 17. | APD $_{17}$ | 24 | 76 |
| 18. | VPD $_{18}$ | 28 | 84 |
| 19. | VPD $_{19}$ | 12 | 92 |
| 20. | KPD $_{20}$ | 0 | 84 |
| 21 | KPD $_{21}$ | 0 | 68 |
| | Average | 36.57 | 79.04 |
| | *N-Gain Score* | 0.67 | Moderate |

Based on Table 6, the calculation of the N-Gain test for each learning style yielded an average score for students with an auditory learning style of 0.64, which falls into the medium category. The average score for students with a visual learning style was 0.69, and also belonged to the medium category. The average score for students with a kinesthetic learning style was 0.68, also in the medium category. Based on each average score obtained, it can be identified that the highest N-Gain score was for the visual learning style, followed by the kinesthetic learning style, and the lowest was the auditory learning style. However, the obtained data show that the three average scores are not significantly different and all fall into the medium category (Majdi et al., 2018). This indicates that the ESW with process differentiation learning on chemical kinetics material is quite effective in improving student learning outcomes or abilities according to their respective learning styles. Therefore, the implemented ESW with process differentiation on chemical kinetics material is statistically proven effective in increasing student learning outcomes. The level of this increase's effectiveness, when measured using N-Gain, is in the "Medium" category (average N-Gain 0.67), meaning it successfully achieved the potential increase expected by the authors (Septiyani, 2015). Learning outcomes or abilities according to their respective learning styles. Therefore, the implemented ESW with process differentiation on chemical kinetics material is statistically proven effective in increasing student learning outcomes. The level of this increase's effectiveness, when measured using N-Gain, is in the "Medium" category (average N-Gain 0.67), meaning it successfully achieved the potential increase expected by the authors (Septiyani, 2015).

The next stage is the evaluation stage, where the student responses are gathered to assess the product. This is done by having students fill out a response questionnaire containing comments and suggestions regarding the use of the ESW with process-differentiated instruction on the topic of chemical kinetics. The evaluation is carried out based on the comments and suggestions provided for the product developed by the researcher to ensure the product is suitable for the learning

process. The students' assessment indicates that the developed ESW with process differentiation on the topic of chemical kinetics is highly suitable for the learning process, engaging, easy to use, and provides an appealing learning experience that aligns with the students' learning styles.

## Conclusion

Based on the results of research and development of ESW with Process Differentiation Learning on Chemical Kinetics Material, it can be concluded that the product incorporating process differentiation learning on the topic of chemical kinetics was successfully developed using the ADDIE development model. The product has met the criteria of valid, effective, and practical. The product has a "Very Valid" level of validity with a validity score of 90.2%. The product's level of effectiveness, measured using N-Gain, is in the "Moderate" category, with N-Gain scores for the auditory learning style is 0.64, the visual learning style is 0.69, and the kinesthetic learning style is 0.68. This indicates that the ESW with process differentiation learning on chemical kinetics material is quite effective in improving students' learning outcomes or abilities in accordance with their learning styles. From the practicality aspect, the ESW obtained a score of 1211, with the respondents' level of agreement in the "Strongly Agree" category regarding the statements in the response questionnaire. This shows that the developed product is considered practical, easy to use, and can be implemented in learning.

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