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Development of Environmentally Based E-STUDENT WORKSHEET for Chemistry Practices

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Abstract. Chemistry learning, particularly in the context of reaction rates, is often considered complex and abstract, necessitating innovative learning media that can effectively link concepts to real-world contexts. One solution is the development of electronic-based teaching materials in the form of E-Student Worksheet (Electronic Student Worksheets) that utilize environmental issues as a contextual approach. This study aims to develop an Environmentally Based Chemistry Practicum E-Student Worksheet on reaction rates that is valid, practical, and suitable for use as a learning medium. The research method employs the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) development model. The research respondents included two media experts, two material experts from Chemistry Education lecturers, and 24 high school teachers who assessed the product quality. The results showed that the assessment by the media experts and material experts obtained an average score of 82%, which is categorized as very good. In addition, a limited trial with high school teachers yielded an average score of 87%, indicating that the E-Student Worksheet received a positive response and was well-received as a learning medium. Based on these findings, it can be concluded that the Environmentally Based Chemistry Practical E-Student Worksheet utilizes the Flipbook Builder application in a manner that meets the needs of students, is suitable for learning, and has the potential to enhance the understanding of chemical concepts through an environmentally based contextual approach.

Keywords: E-Student Worksheet, reaction rate, environment-based, media development.

1 Introduction

Learning reaction rates is often perceived as abstract because it requires the integration of macroscopic, microscopic, and symbolic (triple-M) representations simultaneously, starting from observing rate changes, modeling effective collisions, to the mathematical formalism of reaction order. Various recent studies show that there are still high levels of misconceptions on the topic of factors that influence reaction rates (concentration, temperature, catalysts, surface area), for example, the mistaken belief that any increase in concentration necessarily accelerates the reaction or that the catalyst is "used up" in the reaction [1]–[3]. The pedagogical consequences are low conceptual understanding and difficulty linking concepts to contextual phenomena close to students' lives. A context-based approach is therefore recommended to bridge this gap because it has been proven to improve students' cognitive, affective, and psychomotor aspects in chemistry learning [4]. In this study, contextualization is not merely illustrative but is deliberately aligned with environmentally relevant phenomena, positioning reaction rate learning as a meaningful gateway to sustainability literacy.

In line with global and national needs, chemistry education is now geared towards contributing to sustainability literacy through green and sustainable chemistry education (GSCE) and systems thinking. A recent systematic review (2000–2024) highlighted a growing trend of integrating sustainability into higher education chemistry curricula, while other studies emphasized green chemistry-based learning experiences as effective means to equip prospective teachers with the competence to teach sustainability issues authentically [5],[6]. Strengthening the environmental context in reaction rate laboratories, for example, examining the effects of natural catalysts, household waste, or pollutant degradation processes—aligns with this agenda by simultaneously promoting scientific literacy, environmental awareness, and ethical responsibility. Such integration situates reaction rate concepts within real-world ecological systems, reinforcing the relevance of chemistry learning to contemporary environmental challenges.

From a theoretical perspective, this approach is grounded in constructivist learning theory and contextual learning, which emphasize that knowledge is actively constructed through meaningful interaction with real-life contexts. Furthermore, the demand for representational fluency in reaction rate topics is addressed through multimedia-supported learning environments that facilitate transitions among macroscopic observations, submicroscopic explanations, and symbolic representations. The use of dynamic visualizations and simulations in the e-LKPD flipbook is consistent with multimedia learning theory, which posits that well-designed combinations of text, visuals, and interactivity can reduce cognitive load and enhance conceptual understanding. In addition, the design rationale is supported by the Technological Pedagogical Content Knowledge (TPACK) framework, ensuring the coherent integration of chemistry content, pedagogical strategies, and digital technology within the learning resource.

The post-pandemic digital transformation has further intensified the need for flexible, adaptive, and interactive learning resources. Electronic student worksheets (e-LKPD) have emerged as effective digital tools that not only present procedural steps for practical work but also provide conceptual scaffolding, formative assessment, and automated feedback. Empirical evidence from Indonesia indicates that e-LKPD and e-modules can improve critical thinking skills, scientific literacy, and learner engagement, including in project-based and green chemistry-oriented learning contexts [7]–[9]. Specifically, flipbook-based learning media have been reported to enhance learning motivation and chemistry learning outcomes through non-linear navigation, rich multimedia integration, and interactive quizzes [10]–[12]. These findings reinforce the pedagogical relevance of developing an environmentally based e-LKPD flipbook that integrates reaction rate content with sustainability themes.

On the design development side, the ADDIE (Analyze–Design–Development–Implementation–Evaluation) model remains a mainstream reference in learning design because it is iterative, systematic, and compatible with digital content development and usability evaluation [13]–[15]. In this study, the Analyze and Design stages focus on identifying prevalent misconceptions in reaction rate concepts, learners' digital readiness, and sustainability-related learning needs. The Development stage emphasizes the integration of green chemistry contexts, multimedia elements, and interactive assessments within the flipbook format. Implementation involves limited trials with students and educators, while the Evaluation stage includes expert validation and user feedback to ensure content validity, practicality, and instructional effectiveness. Thus, ADDIE provides a coherent pipeline linking pedagogical goals, environmental relevance, and digital learning innovation.

Importantly, this study moves beyond the mere inclusion of environmental examples by embedding green chemistry principles—such as the use of safer materials, waste minimization, and environmentally benign catalysts—directly into the practicum design. Students are guided to reflect on the environmental implications of reaction rate experiments through structured prompts, inquiry tasks, and evaluative questions within the e-LKPD. As a result, the learning design explicitly connects reaction rate understanding, green chemistry context, and e-learning features in a coherent manner [16], [17]. Moreover, indicators of sustainability literacy and ecological awareness are incorporated into the evaluation components, allowing the study to assess not only conceptual understanding but also students' awareness of environmental responsibility.

Based on this theoretical, empirical, and contextual foundation, the development of a flipbook-based, environmentally oriented e-LKPD for reaction rate practicum is pedagogically justified and environmentally relevant. It holds strong potential to reduce misconceptions through representational support, enhance engagement through interactive digital design, and contribute to measurable improvements in students' sustainability literacy. Consequently, this study offers a robust rationale for positioning digital learning innovation as a strategic vehicle for integrating chemistry education and environmental sustainability in contemporary science classrooms.

2 Method

This research was conducted in January 2025, with the development of the E-Student Worksheet (e-LKPD) reaching the implementation stage through a limited trial. The limited trial was carried out face-to-face at a private senior high school in Jakarta and involved Grade 10 students as users of the product. Several chemistry teachers participated as respondents in the data collection process to evaluate the practicality and pedagogical feasibility of the developed e-LKPD. Prior to implementation, the e-LKPD was subjected to expert validation by one chemistry content expert and one learning media expert. In addition, the teacher response questionnaire used in this study was validated by two chemistry education lecturers to ensure clarity, rele-

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vance, and construct appropriateness. Feedback from these validation stages was used to revise the product before it was piloted in the classroom.

This study employed a Research and Development (R&D) approach using the ADDIE development model proposed by Branch, which consists of five systematic stages: Analyze, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because of its structured, iterative nature and its suitability for developing and validating digital learning resources grounded in learning theory.

At the Analyze stage, a needs analysis was conducted through literature review, informal interviews with chemistry teachers, and analysis of curriculum documents. This stage focused on identifying common student misconceptions related to reaction rate concepts (e.g., concentration effects, catalyst function, and temperature dependence), limitations of existing practicum worksheets, and user needs regarding digital accessibility and environmental contextualization. The analysis also examined opportunities to integrate green chemistry principles into reaction rate experiments in alignment with the national curriculum.

During the Design stage, the instructional flow, learning objectives, assessment strategies, and environmental contexts were mapped out. The e-LKPD was designed to move beyond a static digital worksheet by incorporating inquiry-based practicum activities, contextual green chemistry scenarios, and scaffolding questions aimed at promoting representational fluency (macroscopic–submicroscopic–symbolic). Storyboard layouts and navigation structures for the flipbook format were also developed at this stage.

The Development stage involved producing the flipbook-based e-LKPD using a digital authoring tool. Interactive features such as kinetic animations, short experiment videos, conceptual checkpoints with automated feedback, reflective prompts on environmental impact, and embedded formative quizzes were integrated. These elements were intentionally designed to address identified misconceptions and to enhance student engagement, distinguishing the product from a mere digital conversion of conventional worksheets. The draft product was then submitted for expert validation.

The Implementation stage consisted of a limited trial involving Grade 10 students and chemistry teachers. Teachers observed the use of the e-LKPD during practicum activities and subsequently completed response questionnaires evaluating its usability, clarity, interactivity, and pedagogical usefulness.

The Evaluation stage was conducted formatively throughout the development process and summatively after implementation. Evaluation included expert validation, teacher response analysis, and product revision based on quantitative scores and qualitative feedback. This ensured that the final product met standards of content accuracy, environmental relevance, curriculum alignment, and media quality.

The research instruments used in this study consisted of (1) material expert validation sheets, (2) media expert validation sheets, and (3) teacher response questionnaires. Content validation criteria included subject matter accuracy, alignment with reaction rate learning objectives, integration of green chemistry principles, and relevance to the senior high school chemistry curriculum. Media validation criteria cov-

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ered usability, navigation structure, visual design, interactivity, and technical functionality.

All validation instruments employed a five-point Likert scale ranging from 1 (Very Poor) to 5 (Very Good). The Likert scale was used to measure the degree of agreement with each validation statement. Quantitative data from expert validation were analyzed using descriptive statistics and content validity indices (CVI) to ensure rigor and replicability, while qualitative comments were used as the basis for revision. Teacher response data were similarly analyzed to determine the practicality and acceptance level of the e-LKPD.

Through this systematic execution of all ADDIE stages and the use of clearly defined validation criteria and instruments, the study ensures that the developed flipbook-based e-LKPD represents a pedagogically innovative digital learning resource that effectively integrates reaction rate concepts, green chemistry contexts, and interactive e-learning design rather than functioning as a simple digitization of traditional worksheets.

3 Result

This study collected data on the development process of the E-STUDENT WORKSHEET (Electric Student Worksheet) for reaction rates using the Flipbook Builder application as a tool. Furthermore, data were obtained through a feasibility test conducted using a questionnaire from chemistry teachers at several schools regarding the development of the E-STUDENT WORKSHEET. The complete research results are explained as follows:

3.1 Analysis

The analysis stage aims to collect data related to previous learning activities carried out by teachers and students. This analysis process comprises two main components: a needs analysis and an analysis of learning formulation tailored to the desired objectives. These two components are further explained below.

Needs Analysis

The needs analysis phase involved 28 chemistry teachers as respondents through a questionnaire. The instruments used in this analysis covered several key aspects, namely student interest in reaction rate material, challenges faced in understanding the material, and the use of electronic media in chemistry learning.

Table 1. Results of Needs Analysis

Indicator	Analysis Results
Reaction Rate Material	Students are interested in studying this material because it is closely related to everyday life. Students still find it challenging to understand the concept of reaction rate. Students feel bored because the material is memorized and delivered using the lecture method.

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Obstacles faced	The learning resources used are textbooks, LKPD, and occasionally websites. Students feel bored with the teaching materials provided Teachers have never used E-STUDENT WORKSHEET in learning activities
Utilization of Learning Resources	The use of E-STUDENT WORKSHEET can help improve students' understanding of reaction rates and increase their enthusiasm for learning activities. Teachers hope that the material presented in E-STUDENT WORKSHEET is concise and transparent, making it easy for students to understand. In addition, teachers hope that student activities are offered in an engaging manner so that they can increase students' enthusiasm for learning.

3.2 Design

The design stage can be carried out through several steps, namely material analysis, task analysis, and formulating an assessment strategy. All steps can be outlined as follows:

Material Analysis

Material analysis will be conducted to select relevant materials, analyze them, and systematically organize the findings into the primary material that needs to be explained. The main material chosen in this study is the reaction rate and the factors that influence it. The material design in the E-STUDENT WORKSHEET for the topic of reaction rates is structured based on predetermined learning objectives. After presenting the material on reaction rates, the next step is to design the main tasks to be completed by students based on the material discussed.

Formulating Assessment Strategies

Assessment strategies are developed in accordance with the predetermined learning objectives. Assessment in the developed learning media utilizes a multiple-choice format, with a time allocation of 30 seconds per question.

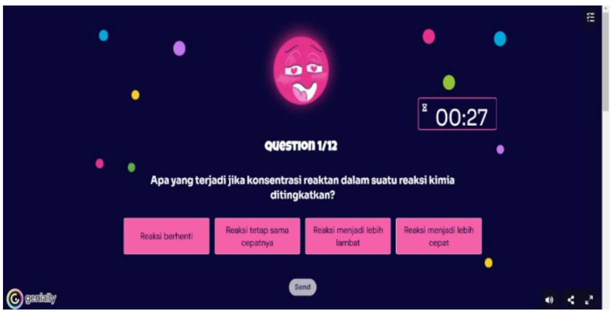

Figure 1. Question Display in the View Genially application

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3.3. Design

The E-Student Worksheet was developed using the Flipbook Builder application. The multimedia content includes: text, illustrations, simple simulations (e.g., the effect of concentration or temperature on reaction rates), videos of simple experiments, and interactive practice questions.

The development phase is the stage undertaken to produce the E-Student Worksheet (E-STUDENT WORKSHEET) on reaction rate factors and instruments for measuring the performance of learning media. The results of this phase are outlined as follows:

E-STUDENT WORKSHEET Development Process

The learning media consists of three main parts: the beginning, the core, and the end.

Beginning

The initial part of the E-Student Worksheet includes the cover and introduction, which consist of initial competencies, the Pancasila Student profile, learning objectives, and user instructions. The cover aims to provide an overview of the learning media's content while also attracting the reader's attention. It consists of two parts: the front cover and the back cover.

(a) (b)

Figure 2. E-STUDENT WORKSHEET Cover Appearance (a) Front, (b) Back

The introduction is a section that contains initial information that participants must know and understand before the learning process begins, making it easier for them to follow during the learning process.

Core

The core activities of the Flipbook Builder learning media on reaction rates consist of materials and student activities. The reaction rate material presented includes information related to the definition of reaction rate, the effects of concentration, temperature, surface area, and catalysts.

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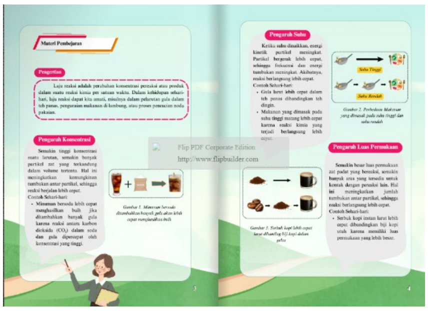

Figure 3. Core Material Display

E-STUDENT WORKSHEET Validation Process

After the validation sheet is compiled, the developed E-STUDENT WORKSHEET undergoes material and media validation testing to assess its feasibility and quality.

Table 2. Material and Media Validation Results

Aspect	Validator 1	Validator 2	Average
Material	78%	86%	82%
Media	82%	82%	82%

Based on the results of the material and media validation conducted by the validator, it can be concluded that the E-STUDENT WORKSHEET prepared meets the eligibility criteria for use. This is in accordance with Table 2, which serves as a guideline for interpreting the validation results scores.

Table 3. Media Expert Validation Results

Assessment Aspects	Score	Category
Display & Graphic Design	85	Very Good
Navigation & Interactivity	80	Very Good
Readability & Typography	82	Very Good
Multimedia Integration	81	Very Good
Average	**82**	**Very Good**

Table 4. Material Expert Validation Results

Assessment Aspects	Score	Category
Conceptual validity	83	Very Good
Curriculum alignment	80	Very Good
Environmental issue integration	82	Very Good
Content and evaluation integration	83	Very Good
Average	**82**	Very Good

3.4. Implementation

After the E-Student Worksheet was developed, the next step was to conduct a limited trial. This trial was conducted with 24 chemistry teachers from various schools to identify teacher responses to the developed E-Student Worksheet. In this trial, teachers assessed the overall module content based on several key components, including guidance and information, multimedia materials, media facility design, and pedagogical impact. The following are the results of teacher responses to the developed E-Student Worksheet.

Table 3. Teacher Response Questionnaire Results

Indicator	Average Percentage	Category
Guidelines and Information	89%	Very Good
Multimedia Materials	86%	Very Good
Media Design and Facilities	87%	Very Good
Pedagogical Effects	88%	Very Good
Average Total	87%	Very Good

4 Discussion

4.1. Significance of Validation Findings: Feasibility of Content, Design, and Usability

The validation score obtained from material experts and media experts (82%, categorized as *very good*) indicates that the developed e-LKPD fulfills the three core pillars of quality instructional media: content validity, media validity, and practicality. Content validity reflects the accuracy of reaction rate concepts, alignment with the senior high school chemistry curriculum, and coherence between learning objectives and practicum activities. Media validity encompasses interface design, navigation structure, interactivity, and technical functionality, while practicality relates to ease of use and instructional clarity during classroom implementation.

These findings are consistent with previous E-LKPD and e-module development studies in Indonesia, which commonly report expert feasibility scores in the range of 80–95% prior to broader implementation. For instance, a JPPIPA study on flipbook-based E-LKPD development using Flip PDF Professional reported an initial feasibility score of 76.7% that increased following expert-driven revisions, while other studies documented post-validation scores exceeding 85–90% for digital chemistry learning media [17]. Such convergence across studies reinforces the robustness of expert validation as an initial indicator of classroom readiness.

From a methodological standpoint, the results confirm the systematic and appropriate execution of all ADDIE stages. The Analyze stage enabled the identification of prevalent misconceptions in reaction rate learning and teachers' needs for interactive, environmentally contextualized practicum materials. The Design and Development stages translated these findings into structured content layouts, interactive media components, and inquiry-based tasks. Implementation through limited trials allowed for real-user interaction, while Evaluation involved expert validation, teacher feedback, and iterative revisions. This cyclical process aligns with recent instructional design literature, which emphasizes that ADDIE's strength lies in its feedback loops and evidence-based refinement at each stage [16]

4.2. Validation Rigor: Criteria, Instruments, and Replicability

The rigor of the validation process in this study is supported by clearly defined validation criteria and the use of standardized instruments. Material expert validation criteria included (1) subject matter accuracy of reaction rate concepts, (2) alignment with green chemistry principles and environmental sustainability themes, and (3) relevance to curriculum competencies. Media expert validation criteria addressed usability, clarity of navigation, visual consistency, interactivity, and the effectiveness of multimedia elements.

All validation instruments employed five-point Likert-scale rubrics, enabling quantifiable assessment of each criterion. Quantitative data were analyzed descriptively and supported by Content Validity Index (CVI) analysis, which strengthens methodological transparency and allows replication in future studies. Qualitative feedback from experts was systematically used to revise content explanations, refine navigation flow, and enhance interactive components. This combination of quantitative scoring and qualitative revision aligns with best practices in educational product validation and ensures that the development process is both rigorous and reproducible

4.3. Pedagogical Innovation of the Flipbook-Based e-LKPD

Importantly, the developed flipbook-based e-LKPD demonstrates genuine pedagogical innovation rather than functioning as a mere digital conversion of conventional worksheets. Unlike static PDF worksheets, the e-LKPD integrates kinetic animations, short experiment videos, interactive simulations, and embedded formative assessments with automated feedback. These elements are deliberately designed to address common misconceptions in reaction rate concepts, such as misunderstandings about catalyst behavior or concentration effects.

The inclusion of feedback loops and conceptual checkpoints allows students to test their understanding in real time, supporting conceptual change and representational fluency across macroscopic, submicroscopic, and symbolic levels. This design is consistent with multimedia learning theory and constructivist principles, which emphasize active engagement and immediate feedback as key drivers of meaningful learning. The flipbook format further enhances engagement through non-linear navigation and multimodal content, positioning the e-LKPD as an interactive learning environment rather than a static instructional aid.

4.4. The Relevance of Environmental Context: From Context-Based Learning to Green & Sustainable Chemistry Education

The integration of environmental contexts within the reaction rate practicum extends beyond contextual examples and aligns with **Green & Sustainable Chemistry Education (GSCE)** and systems thinking frameworks. By engaging students with environmentally relevant experiments—such as natural catalysts, waste-related reaction systems, or pollutant degradation—the e-LKPD facilitates the application of abstract reaction rate concepts to real-world sustainability challenges. Systematic reviews of context-based chemistry learning consistently report positive effects on conceptual understanding and affective outcomes, particularly when students can connect symbolic representations with everyday phenomena [4].

Moreover, recent GSCE literature emphasizes that sustainability-oriented chemistry education should foster not only content mastery but also ecological awareness and sustainability literacy [5], [18]–[20]. Through reflective prompts and evaluative questions embedded in the e-LKPD, students are encouraged to consider the environmental implications of chemical processes. While this study primarily focused on feasibility and validation, the design provides a foundation for future research to quantitatively measure gains in sustainability literacy and environmental attitudes.

4.5. Teacher Acceptance: Indicators of Readiness for Implementation

Teacher responses (average score of 87%, categorized as *very good*) indicate strong acceptance of the e-LKPD in terms of usability, instructional clarity, and relevance to classroom needs. Teachers highlighted the practicality of the interface, the clarity of practicum flow, and the relevance of environmental contexts to school and community-based projects. These findings are comparable to other Indonesian digital media development studies reporting teacher acceptance scores ranging from 81% to 100%, suggesting that the product is ready for classroom adoption with only minor refinements [21]. Overall, the discussion confirms that the ADDIE model was systematically applied, the validation process was rigorous and transparent, and the resulting flipbook-based e-LKPD constitutes an innovative, theory-informed learning resource. It effectively integrates reaction rate concepts, environmental sustainability, and interactive digital design, thereby supporting both pedagogical advancement and sustainability-oriented chemistry education

5 Conclusion

The Environmentally Based Chemistry Practical Worksheet (LKPD) on reaction rates developed using the ADDIE model was declared highly feasible based on expert validation (82%) and teacher responses (87%). This product can increase learning motivation, strengthen conceptual understanding, and foster environmental awareness in students.

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