



Development of Guided Inquiry-Oriented Electronic Student Worksheets to Improve Students' Metacognitive Skills on Chemical Equilibrium Material

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ABSTRACT

Metacognitive skills are important to train students in developing and improving 21st century skills. One of the efforts to train metacognitive skills in students by using relevant learning media, namely guided inquiry-oriented electronic student worksheets. This research aims to determine the feasibility of developing a guided-inquiry-oriented student e-worksheet to improve metacognitive skills on chemical equilibrium. The feasibility to use, in terms of validity, practicality, and effectiveness. The method used in this research is R&D with a 4D model, but only reached the develop. The subjects of this study amounted to 20 students of class XI-1 SMAN 21 Surabaya. The results obtained are that the student e-worksheet developed is feasible because the validity results the content and construct in mode 5 with a very valid category. The practicality results obtained a student response questionnaire of 95,29% in the very practical category and supported by the results of observations of student activities obtained a percentage of 92,78% in the very practical category. The effectiveness results were obtained from the pretest and posttest results, which analyzed using the SPSS *Paired Sample t-Test*, the results showed that there was an increase in students' metacognitive skills, namely with a sig. value (two-sided p) 0.001.

INTRODUCTION

Education is one of the essential components for the progress of a country because a country is said to be advanced if education in that country is of good quality and good role of the government to advance the quality of education in Indonesia has made various efforts, one of which has occurred several times changing the curriculum in an effort to improve the quality of Indonesian education. Currently, the government is creating and implementing the Merdeka Curriculum based on the Ministry of Education and Culture No. 56/M/2022 regarding curriculum implementation guidelines in learning recovery efforts. The Merdeka Curriculum is closely related to improving and developing the skills needed in the 21st century. Metacognition is one of the innovative skills in 21st-century learning and high-level cognition processes that include thinking about knowledge and how to gain that knowledge through a reflective process (Azizah & Nasrudin, 2021).

Metacognitive skills are mental abilities that consciously be arranged, controlled, and examined for their thinking processes (Azizah et al., 2019). Metacognitive skills are an essential component in completing graduation standards in the Merdeka curriculum (Maghfiroh & Susantini, 2023). Learning with metacognitive skills focuses on students' learning activities, assisting and guiding students if there are difficulties, and helping students develop self-concepts about what they do when learning chemistry

(Azizah et al., 2020). Metacognitive skills are activities used to control their cognition which includes planning skills, monitoring skills, and evaluating skills (Nuryana & Sugiarto, 2012).

Students with good metacognitive skills tend to be able to find solutions to problems by using conscious student thinking (Fitriah, 2023). However, some research results show that students in various schools in the Indonesian region have low metacognitive skills (Nurajizah et al., 2018). One sign of low student metacognitive skills is the lack of ability to develop thinking processes in solving problems, lack of using prior knowledge, organizing information obtained, how and when to apply strategies, lack of managing learning strategies used effectively, and application of knowledge that has been learned (Konita, 2017). Based on this problem is supported by the results of a pre-research questionnaire conducted on students at SMAN 21 Surabaya showing that students' metacognitive skills in planning skills reached 42.86% with a deficient category, monitoring skills reached 39.99% with a deficient category, and evaluating skills reached 39.04% with a very deficient category. The results explain that students at SMAN 21 Surabaya are not accustomed to using metacognitive skills during the learning process.

Chemistry is the study of substances related to the composition, structure, properties, changes, dynamics, and energetics of substances that require skills and reasoning (Indranityati et al., 2020). Chemical equilibrium is one of the materials included in the Learning Outcomes of Phase F in the Merdeka curriculum. At the end of Phase F, it is stated that students can understand and explain the equilibrium of a chemical reaction. Based on the results of a pre-research questionnaire which state that 74% of the students said that equilibrium material was challenging to learn, and 62% of the students said that the sub-material of factors affecting the shift in the direction of equilibrium was a sub-material that was difficult to understand because sometimes there was a mistake in determining the direction of the equilibrium shift. Learning that is contextual and observing changes in the color of the solution in the equilibrium system can help students understand and explain the causes of shifts in chemical equilibrium. However, so far, learning this material has only been done by memorizing concepts that occur due to shifts in chemical equilibrium through an experiment, so students lack meaning in learning (Sukeimi, 2022).

Metacognitive skills are needed in chemical equilibrium material because it requires students to actively and independently participate in learning activities by experimenting to identify chemical equilibrium shift reactions so that students can understand the learning strategies that will be used for their understanding (Slavin, 2018). Based on the results of research by Izzah & Azizah (2019) that, students' metacognitive skills can be trained through guided inquiry learning models. The inquiry-based learning model is an active, student-centered, and independent learning model that makes students responsible for their learning (Hasanah, 2021). Learning using the guided inquiry learning model can improve students' metacognitive skills because it helps students find the right strategy in the learning process (Andriyanto et al., 2021). The guided inquiry learning model has stages that reflect the components of students' metacognitive skills (Aprilia & Sugiarto, 2013). According to the results of Danila & Agustini's research (2021), learning using the guided inquiry model has a significant effect on students' metacognitive skills.

Teaching materials are needed during the learning process to help students understand concepts (Sagita et al., 2017). One type of printed teaching material that teachers most often use is LKPD (Dermawati et al., 2019). As technology advances today, most students are more interested in teaching materials that are accessed through other media, such as computers, laptops, or smartphones, rather than printed teaching materials. According to Syahputri et al. (2023), one of the teaching materials that utilizes technology is the Electronic Student Worksheet (e-Worksheet). One of the websites that provide services for using e-Worksheet is *liveworksheet*. Learners can easily use *liveworksheet* because they can work directly on the site without downloading or registering to access student worksheets that have been uploaded (Masruhah et al., 2022). An e-worksheet with a guided inquiry model can help students find concepts through activities they can carry out themselves or by learning in groups so that the learning process becomes more meaningful (Latifah, 2016). Making student e-worksheets integrated with metacognition will help students construct their abilities so that they become critical and reflective students who automatically become independent learners (Surata et al., 2018).

Given the challenges outlined, it is crucial to undertake a research initiative titled “Development of Guided-Inquiry-Oriented Electronic Student Worksheets (e-Worksheet) to Improve Students’ Metacognitive Skills on Chemical Equilibrium Material”. This research has the potential to create electronic student worksheets that can significantly enhance metacognitive skills in students, paving the way for a more promising future for education in Indonesia.

RESEARCH METHODS

Research Approach

The type of research used is Research and Development (R & D). Research and development is a research method used to produce specific products and test their effectiveness (Sugiyono, 2017). The research design used is based on the research and development model using the 4D model by Thiagarajan (1974). The 4D model consists of stages: (1) define, (2) design, (3) develop, and (4) disseminate. However, this research is limited to the develop stage with a limited trial to determine the feasibility of the product in the form of electronic student worksheets using liveworksheet. In the product trial, a one-group pretest-posttest design was used.

Research Participants

The subjects of this research were SMAN 21 Surabaya class XI students, totaling 20 students who had received chemical equilibrium material. Data sources in this study were obtained from validators and 20 students of class XI-1 at SMAN 21 Surabaya. The object of this research is a guided inquiry-oriented electronic student worksheet product using liveworksheet to improve metacognitive skills on chemical equilibrium material.

Research Instruments

The instruments used in this study are:

1. Validation Sheet
The validation sheet is used to determine the validity of the product. This validation sheet is needed to develop a product, which will be given to the validator. In this study, validation was carried out by three validators.
2. Student Response Questionnaire Sheet
The student response questionnaire sheet was given after the product trial was completed. The results of the student response questionnaire sheet are used to determine the practicality of the product.
3. Student Activity Observation Sheet
The student activity observation sheet was used during the product trial and filled in by the observer. The results of the student activity observation sheet are used for supporting data to determine the practicality of the product.
4. Test Sheet
The test sheet is given to students in the form of pretest and posttest sheets in the form of description questions containing components of metacognitive skills (planning skills, monitoring skills, and evaluating skills). The metacognitive skills test sheet is used to determine the effectiveness of the product.

Data Collection

The data collection techniques used in this study are:

1. Questionnaire Method
The questionnaire method is used to collect validation data and student responses. Validation is needed to determine the validity of products that have been made or developed by researchers. In this validation, three validators provide input or comments and then provide an assessment of the product developed. The validator's assessment consists of content validity and construct validity. Student responses were used to determine the practicality of the product developed. This questionnaire responses were filled in by students who were used to obtain data on the responses of students after using guided inquiry-oriented electronic student worksheets during the trial.

2. Observasion Method

The observation method was used to collect data on student activity. This method was filled in by six observers, each of whom observed one group of 6-7 students by observing each activity and behavior of students every 3 minutes during the trial using the developed electronic student worksheet. Data on student activity results are used as supporting data to determine the practicality of the developed product.

3. Tes Method

The test method is used to collect metacognitive skills test data. The test used is in the form of description questions in the form of pretest and posttest questions which contain components of metacognitive skills (planning skills, monitoring skills, and evaluating skills) in answering questions. The pretest questions were given to students outside the allocation of learning time, namely before the first meeting and the posttest was given outside the allocation of learning time after the trial of the developed product. Metacognitive skills test data is used to determine the effectiveness of the developed product.

Data Analysis

The development of electronic student worksheets developed is feasible to use, in terms of validity, practicality, and effectiveness. The following is the analysis used in this study.

1. Validation Analysis

The validation results are used to determine whether the electronic student worksheets developed are valid or invalid. The validation results include content validity and construct validity. The validation analysis uses quantitative descriptive with reference to the Likert scale assessment criteria in Table 1 below.

Table 1. Likert Scale

Value/Score	Category
1	Very Invalid
2	Invalid
3	Fairly Valid
4	Valid
5	Very Valid

(Riduwan, 2015)

The validation data is ordinal data which has the nature that mathematical operations cannot be performed, so the determination is made by mode. This means that the decision is made on the largest number. However, if the mode value is not found, the median method can be used (Gulo, 2002). The validation results were declared valid if they obtained a mode with a value of 4 in the valid category or 5 in the very valid category.

2. Practicality Analysis

Practicality analysis was determined from student response questionnaires and student activity observations. The student response questionnaire was analyzed using descriptive quantitative referring to the Guttman scale assessment criteria in table 2 below.

Table 2. Guttman Scale

Answer	Score
1	Very Invalid
2	Invalid

(Riduwan, 2015)

After get the score, it will be analyze with the percentage formulas below.

$$\% = \frac{\sum \text{score obtained}}{\sum \text{maximum score}} \times 100\%$$

The percentage that produced will be interpreted according to the categories shown in Table 3. below.

Table 3. Percentage of Practicality

Value/Score	Category
1	Very Invalid
2	Invalid
3	Fairly Valid
4	Valid
5	Very Valid

(Riduwan, 2015)

Based on Table 3. Above, electronic worksheet is said to be practical to very practical if the response questionnaire data are obtained with a percentage of $\geq 61\%$.

In the observation of student activities carried out by six observers with each observing one group containing 6-7 students every 3 minutes was analyzed descriptively quantitatively based on the average observation results from six observers using the following formula.

$$\% = \frac{\sum \text{frequency or relevant learner activities}}{\sum \text{the frequency of overall activity}} \times 100\%$$

The percentage that produced will be interpreted according to the categories shown in Table 3. The results of activity observations are said to support the assessment of the practicality of the electronic worksheet use liveworksheet is said to be practical or very practical if the relevant learner activities are $\geq 61\%$ of the percentage of irrelevant learner activities.

3. Effectiveness Analysis

Effectiveness is reviewed from the results of pretests and posttests given to students. The calculation is done by calculating the paired sample t-test with the condition that the data must be normally distributed using SPSS software. The normality test used in this study was the Shapiro-Wilk technique with SPSS because the sample used in the study was small in scale (50 data). In the Shapiro-Wilk test, if the significance level is >0.05 , the data is normally distributed, but if the significance level is <0.05 , the data is not normally distributed (Nuryadi et al., 2017). If the data is normally distributed, then a paired sample t-test will be conducted. This test is used to determine the significance of the difference between pretest and posttest scores using SPSS (Nuryadi et al., 2017). The decisions on the paired sample t-test can be seen from the sign value or significance level (two-sided p), with the criteria if (significance value. <0.05), so it can be interpreted that there is an average difference between the pretest and posttest scores of students' metacognitive skills. This means that the electronic worksheet uses liveworksheet-oriented guided inquiry, which is said to be effective. But if (significance value. >0.05), it can be interpreted that there is no average difference between the pretest and posttest scores of students' metacognitive skills, and this means that the electronic worksheet uses live worksheet oriented guided inquiry is said to be ineffective. However, if the data is not normally distributed (significance <0.005), proceed with non-parametric statistical analysis (Wilcoxon signed ranks test) for the alternative Paired Sample t-test (Danila & Agustini, 2021).

RESULTS AND DISCUSSION

Results

This study applies the phases of the 4D model proposed by Thiagarajan, namely, define, design, develop and disseminate. However, this study is limited to the develop phase only. The define phase aims to find out the potential learning problems faced by students related to the creation of electronic student worksheets. This phase consists of five analysis steps: initial and final analysis, student analysis, task analysis, concept analysis and learning objective analysis. The initial and final analysis includes the

analysis of the curriculum used, i.e., the Merdeka Curriculum. The Merdeka curriculum requires students to be active learners and to have metacognitive skills. Metacognitive skills are necessary to understand conceptual material on chemical equilibrium, which is characterized by the proof of material through experiments, and students must use their own thought processes. Based on these characteristics, the guided inquiry model can be used and applied. In addition, the learning process requires appropriate learning media, such as: B. Electronic worksheets for students. In the analysis stage of students, cognitive development and metacognitive skills are analyzed. This shows that students in the formal operational stage (16-18 years old) are cognitively developed and therefore already able to think abstractly, but the metacognitive skills of students are still relatively poor. . The task analysis phase aims to determine the tasks that students need to complete to improve their metacognitive skills adapted to guided inquiry learning. Conceptual analysis produces a concept map of the material to be presented in the electronic student worksheets. In the final phase, the analysis phase, learning objectives for the material are formulated based on factors influencing the transition to chemical equilibrium, in accordance with the learning outcomes of Phase F of the Merdeka curriculum.

The design phase aims to design the initial design of the development product. The design phase includes (1) preparing a test of metacognitive skills on factors influencing the transition to chemical equilibrium in the form of a pre-test and a post-test. The developed test of metacognitive skills includes 10 short-answer questions with components of metacognitive skills, up to 4 questions on planning skills, and up to 3 questions on monitoring and evaluation skills. (2) selecting a format of teaching materials in the form of electronic student worksheets that fit the guided inquiry learning model and can train metacognitive skills. (3) The initial design of the electronic student worksheets using Liveworksheet refers to Depdiknas (2008). In this study, one main student worksheet and three student worksheets corresponding to materials on factors influencing the transition to chemical equilibrium are included. Electronic Student Worksheet 1 or Master Sheet contains identity and developed student worksheets, Electronic Student Worksheet 2 contains guided learning on concentration factors, Electronic Student Worksheet 3 contains guided learning on temperature factors, Electronic Student Worksheet 4 contains guided learning on temperature factors. Factors of pressure and volume. The format of Student Worksheet 1 or Main Sheet contains several components such as cover page, introduction, concept map, general directions, instructions for use, task instructions, learning outcomes, learning objectives, set of learning objectives, menu options to access Electronic Student Worksheet. Each chemical balance factor and bibliography. The other three student e-worksheets (concentration coefficients, temperature coefficients, pressure and volume coefficients) have the same format, including a cover page, work instructions, a set of learning objectives, and a set of activities related to the phase/syntax. Guided Learning Model. During the design phase, the first drafts of the student e-worksheets were created in the form of PDF files that were edited using Canva and Microsoft Word applications.

The develop stage aims to perfect the product results from the design stage to produce the final product of guided inquiry-oriented electronic student worksheets. At this stage, the review stage is carried out first by the supervisor in the form of suggestions and comments, after being revised, it will produce draft II which is then uploaded to the liveworksheet website. After that, the validation stage was carried out by 2 chemistry lecturers at Universitas Negeri Surabaya and 1 chemistry teacher at SMAN 21 Surabaya. The validation stage aims to provide an assessment of the electronic student worksheet products developed. The aspects assessed were content validity and construct validity. The validation results can be seen in Table 4. below.

Table 4. Validation Result

Validity	Mode	Category
Content	5	Very Valid
Construct	5	Very Valid

Based on the data in Table 4. it can be seen that the results of the validation of electronic student worksheets in terms of content validity and construct validity get mode 5 with a very valid category, which means that guided inquiry-oriented electronic student worksheets are valid to use as teaching materials.

After the product is declared valid, a limited trial is carried out to determine the practicality through the results of the learner response questionnaire and the results of observation of learner activities and to determine the effectiveness through the results of the learner's metacognitive skills test. The trial was conducted on students of class XI-1 at SMAN 21 Surabaya with a total of 20 students. The practicality of electronic worksheet use liveworksheet is reviewed from the result the learner response questionnaire and the results of observation of learner activities. Students' response questionnaire contained three different purposes. The result of student response data can be seen in Table 5. below.

Table 5. The Result of Student Respon Data

Purpose	%	Category
Knowing the ease of use of electronic worksheets oriented guided inquiry	97	Very Practical
Knowing the usability of use of electronic worksheets oriented guided inquiry	93,33	Very Practical
Knowned the usability of electronic worksheets oriented gurided inquiry on metacognitive skills	95,55	Very Practical
Average	95,29%	Very Practical

Based on the data in Table 5, the percentage is obtained in the very partical category, so that electronic student guided inquiry-oriented worksheet is said to be vary practical in term of the results of the student response questionnaire. Meanwhile, the result for student activity observation data can be seen at Table 6. below.

Table 6. The Result of Student Observation Data

Meeting	Average Observation Results of Relevant Learner Activities (%)	Category
First	92,22%	Very Practical
Second	92,78%	Very Practical
Third	93,33%	Very Practical

Based on the data in Table 6, the results of observations of student activity in the first, second, and third meetings with the percentage of relevant student activity $\geq 61\%$ with a very practical category, so that electronic student worksheets using liveworksheet are declared practical to use as teaching materials.

The effectiveness of electronic worksheet use liveworksheet is reviewed from the result of pretest and posttest test using paired sample t-test with the condition that the data must be normally distributed. The result of normality test of the data can be seen on the Table 7. below.

Table 7. Normality Test Result Data

	Statistic	Shapiro-Wilk	
		df	Sig.
Pretest	.907	20	.056
Posttest	.939	20	.233

Based on the data in Table 7, the normality test was carried out with Shapiro Wilk because it used data < 50 and obtained a pretest significance value of 0.056 and a posttest significance value of 0.233. Both data were declared normally distributed because they obtained a significance value > 0.05 . Because the data is normally distributed, it can be tested using paired sample t-test. The results of the paired sample t-test can be seen in Table 8. Below.

Table 8. Paired Sample t-Test Result Data

	Mean	Std. Deviation	Std. Error Mean	95% confidence interval of difference		t	df	Significance
				Lower	Upper			Two – Sided p
<i>pretest - posttest</i>	-45.850	11.627	2.600	2.600	-51.292	-17.635	19	<.001

Based on the data in Table 8, the paired sample t-test significance value is 0.001. So that electronic student worksheets using liveworksheet are declared effective for improving metacognitive skills because the paired sample t-test results obtained a significance value (two sided p) <0.05.

Discussion

Based on the described findings, this study focuses on the feasibility of the electronic student worksheet in terms of validity, practicality and effectiveness. Based on the obtained validity data, it can be seen that the validation results of the electronic student worksheet obtained mode 5 in the very valid category regarding the results of content validation and construct validation. The results of content validity include criteria components on the fit of the learning outcomes, learning objectives, and flow of learning objectives in the Merdeka curriculum by obtaining mode 4 in the valid category, fit of phenomena with materials, and factors influencing the transition to the objectives; chemistry balance by obtaining mode 5 in the very valid category, fit of content with the guided inquiry model by obtaining mode 5 in the very valid category, and fit of content with components and indicators of metacognitive skills by obtaining mode 5 in the very valid category. Overall, the results of content validity reached mode 5, reaching the very valid category. Construct validity results included components of the graphic criterion by obtaining mode 5 in highly valid categories, the presentation criterion by obtaining mode 5 in highly valid categories, and the language criterion by obtaining mode 5 in highly valid categories. Overall, the results of construct validity received the category “very valid” mode 5. Therefore, the developed electronic student worksheet was classified as “very valid” as it was found to have content and construct validity.

The practicality of the electronic worksheet will be verified based on the results of the questionnaire on student activities and the observation sheet. The questionnaires filled out by the students will be distributed after three learning sessions using the electronic student worksheet to determine the students' reactions to the use of the electronic student worksheet. The questionnaire distributed to the students includes three objectives: the practicality of the ease of use of the electronic worksheet, the practicality of the electronic worksheet in learning using the guided inquiry model, and the practicality of the electronic worksheet to improve metacognitive skills. According to the results of the questionnaire, the average response rate of students who answered "very practical" was 95.29%, which means that the electronic worksheet for students by Liveworksheet is practical as a teaching material. This is consistent with the results of Zuhra et al. who conducted the study. (2019), students' responses to the LKPD were classified as positive 85% of the time. It can be concluded that the guided inquiry-based student worksheets meet the criteria for students to learn as learning resources. The practicality is also supported by the observation sheets of learning activities conducted by observers during learning with the electronic student worksheets. 16 learning activities were observed in each meeting. As a result of the observation of students' activities, the percentage of applicable activities was 92.22% in the first meeting, 92.78% in the second meeting, and 93.33% in the third meeting. The average observation score for the three meetings was 92.78%, which was a practical category that indicates that the electronic worksheets by Liveworksheet can be practically used as teaching materials.

The validity of the electronic student worksheet with Liveworksheet is verified using the results of a pre-test and post-test of metacognitive skills on factors influencing the direction of chemical equilibrium shift. The test consists of 10 short answer questions that contain components of metacognitive skills, including 4 questions on planning skills and 3 questions on monitoring and evaluation skills. The pre-test was administered before learning with the electronic student worksheet with Liveworksheet, and the post-test was administered after learning with the electronic student

worksheet with Liveworksheet. The pre-test and post-test data obtained were analyzed using SPSS version 29. This includes paired samples t-tests under the condition that the data should be normally distributed. If the data are normally distributed, proceed to use paired samples t-tests. The results of data normality test are shown in Table 7. Normality test was performed using the data with Shapiro Wilk of 0.05. As the data is normally distributed, it can be tested using paired sample t-test. The results of paired sample t-test are shown in Table 8. Based on the results of paired sample t-test performed, a significance value of 0.001 was achieved. Electronic student worksheets with guided, exploratory, live worksheets are deemed effective in improving metacognitive skills as determined by paired sample t-tests..

CONCLUSION

Based on the results of the conducted research, it can be concluded that the inquiry-oriented electronic student worksheet is effective in improving metacognitive skills on chemical equilibrium materials in terms of validity, practicality and usefulness. The validity results were checked using content and construct validity and received the very valid category in mode 5. The practicality of the student worksheet is evident in the students' response questionnaire and is supported by the results of the observation of students' activities. In the results of the students' response questionnaire, the percentage of the convenience category reached 95.29%. At the same time, the observation of students' activities revealed that the average percentage of relevant student activities in the three sessions was 92.78%. The effectiveness of the student worksheet is demonstrated by the results in improving metacognitive skills. The results were processed using a paired sample t-test, which gave a significance value of 0.001, meaning that there is a significant difference between the pre-test and post-test. Results of metacognitive skills. This is consistent with the study of Jarlis et al. (2023) who stated that inquiry-based student worksheets are acceptable and can increase students' curiosity, and therefore are suitable as teaching materials for students.

Researchers have used the research and development (R&D) methodology using Thiagarajan's 4D model, limited to the development stage, so that future researchers can reach the dissemination stage. Furthermore, future researchers are expected to train the components of metacognitive skills using the guided inquiry model so that they are balanced and equally important, since the evaluation results of students' skills are low in this study, since only the guided learning model exploration is trained. The final construct of guided inquiry, namely reflection on the problem situation and thought process. It is expected that further research and development of guided, inquiry-oriented electronic student worksheets to improve students' metacognitive skills will be applied to other chemicals so that students' metacognitive skills can be properly trained.

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