International Journal of STEM Education for Sustainability, Vol 1, No.1, 2021, pp. 1-10
e-ISSN 2798-5091. DOI. 10.53889/ijses.v1i1.1

Development of Worksheet Based on Scientific Approach to Improve Critical Thinking Skills

Submitted 28 May 2021, Revised 25 June 2021, Accepted 29 June 2021

Tias Ernawati[1*], Sigit Sujatmika[2]
[1,2]Science Education Program, Faculty of Teacher Training and Education,
Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Indonesia
Corresponding Email: *tias.ernawati@ustjogja.ac.id

Abstract

This study aimed to develop and determine the advisability of chemical worksheets based on a scientific approach to improve students' critical thinking skills. The research method uses five design research steps simplified from Borg's and Gall's research and development. The subject of this research are science education program students at one university in Indonesia. Validation subject matter feasibility on the worksheets is 4.34 (best criteria), while the feasibility is 4.17 (best standards). A random assessment from several students is obtaining an average score of 98.67% (positive response). The research results conclude that a worksheet is advisable for students. Expert opinion conveys that using a scientific approach to the problems presented in the worksheet reveals stimulates, encourages, and improves critical thinking skills.

Keywords: worksheet, scientific approach, critical thinking skills

INTRODUCTION

Science plays a pivotal role in responding to issues during industrial revolution 4.0 to society 5.0. As an integral part of Science, Technology, Engineering, and Mathematics (STEM), science is expected to contribute to the review in developing basic concepts of knowledge as a solution to answer daily life problems. In terms of assessment and development of sciences, sustainable literacy is necessary. There is a critical thinking process in sustainability literacy to recognize, understand, and study scientific cases to find solutions.

Critical thinking is a mental process that seeks to clarify and evaluate the actions and activities of life (Kong, 2007). The cognitive functions of clarification and evaluation are essential in the problem-solving and decision-making processes, which encompass entire daily activities. Thus, critical thinking is one's mental attitude in the form of cognitive abilities. Critical thinking help students to think about how they reach conclusions, defend positions on complex issues, consider a variety of points of view, analyze concepts, theories, and explanations, explain problems and findings, solve problems, transfer ideas to new contexts, examine assumptions, assessing facts, and exploring implications in their thoughts and experiences (Hewitt & Lyons, 2007).

In constructing assessments of critical thinking, educators should use open-ended tasks, real-world or "authentic" problem contexts, and structured problems that require students to go beyond recalling or restating previously learned information (Lai, 2011). In developing critical thinking skills, teachers need basic instruction that can activate students, such as teaching

material. Wotruba and Wright in Uno (2013) revealed the seven effective learning indicators, namely: (1) good material organization, (2) effective communication, (3) mastery and enthusiasm for topics being taught, (4) positive attitudes towards students, (5) fair assessment, (6) flexibility in the learning approach, and (7) good student learning outcomes. To realize the ideal learning process, a collaboration between lecturers and students is obviously significant, supported by learning resources that include appropriate teaching materials and instructional media, methods, and strategies. Teaching materials are all forms of materials used by lecturers to help students perform in the learning processes. The teaching materials platform can be either printed or online, written or unwritten resources.

Through teaching materials, the worksheet based on a scientific approach is expected to make students more productive, creative, innovative, and effective through the strengthening of integrated attitudes, skills, and knowledge. The scientific approach is a learning model that uses scientific principles which contain a series of data collection activities through observation, questioning, experimentation, processing information or data, then communicating (Kementerian Pendidikan dan Kebudayaan, 2013). Students are directed to actively observe, ask, think, experiment, or try to convey and share what they have learned. The objectives of learning with a scientific approach include: (1) increasing intellectual abilities, especially higher-order thinking skills, (2) to form students' abilities in solving a problem systematically, (3) creating learning conditions where students feel that learning is a form of learning. There is a need (4) to obtain high learning outcomes, (5) to train students in communicating ideas, especially in writing scientific articles, and (6) to develop students' character (Machin, 2014).

Learning in a college class is also a description of circumstances that indicates the interaction process involving college students, lecturers, and learning resources in certain conditions called the learning environment. Effective learning can convey students' active participation and potential (Ernawati, 2016). The chemistry course, along with a code of IPA15106, is a compulsory course with two credit points. Chemistry learning has not implemented structured teaching materials such as a worksheet, but lecturers use textbooks and handouts. Students are dependent on the materials presented by the lecturer in the learning process. They have not fully initiated to study the chemical materials before the lecture begins. Critical thinking skills during learning are still low. Students prefer to wait for instructions from the lecturer. Most of them tend to be passive during the lesson.

Instructional materials have some crucial roles in the learning process; one of them is to more interesting, practical, realistic, and meaningful learning (Olayinka, 2016), (Saad, 2017), (Zhang et al., 2016). Related to the problems above, the objective of this research is to develop a chemistry worksheet based on a scientific approach to improve students' critical thinking skills.

METHOD

This research is a development study using a step-by-step approach to develop Borg's and Gall's model. The research procedure was simplified into five steps, namely (1) exploratory study, (2) product design, (3) expert validation and revision, (4) limited and revised testing, and (5) mind field testing and final product (Pusat Penelitian Kebijakan dan Inovasi, 2008). This study did not reach the stage of main field testing due to various limitations experienced by the author. The steps of this research are presented in the following figure.

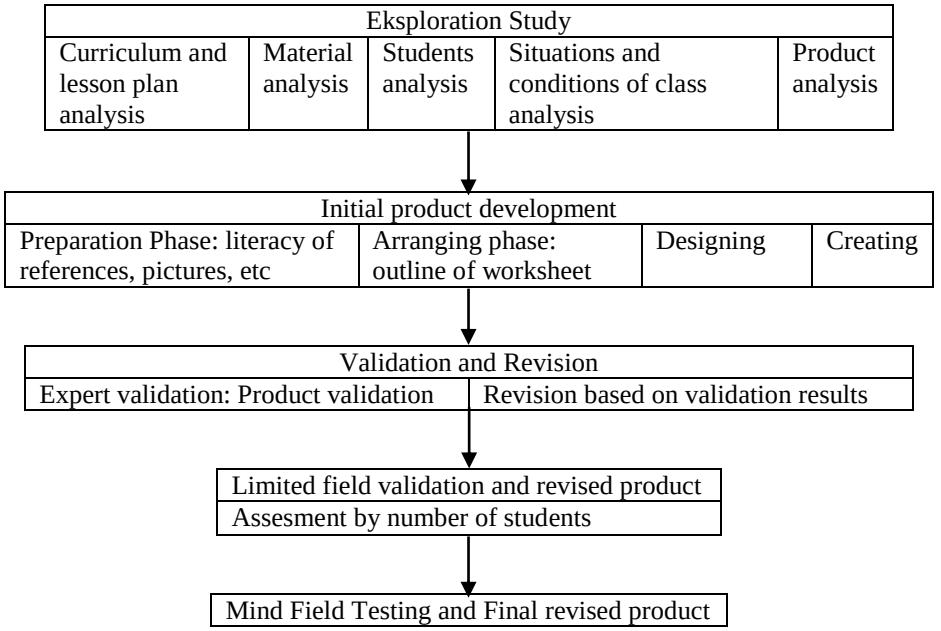

Figure 1. Steps for Making the Worksheet Based on Scientific Approach

Data collection techniques used qualitative and quantitative methods of validation for expert judgments by the Delphi technique. Validation sheets are in the form of a questionnaire of five rating Likert scales. User response is obtained from the assessment of the number of students at random.

RESULTS AND DISCUSSION

Quantitatively, the criteria and value limits of the validation resulted from the validators are to follow the criteria listed. The results of the validation in terms of the material experts and worksheet experts are presented in Table 1, Table 2, Table 3, and Table. 4

Table 1. Validation criteria

Score	Criteria
$\bar{X} > 4$	Best
$3.33 < \bar{X} \leq 4$	Good
$2.67 < \bar{X} \leq 3.33$	Worse
$2 < \bar{X} \leq 2.67$	Bad
$\bar{X} \leq 2$	Worst

The distribution of the assessment criteria from experts is according to Table 1. To get good criteria, the expert at least gives an average score above 3.33. The results of the material expert assessment are in Table 2.

Table 2. Results of material validation by material experts

Validation Indicator	Validation Item	Score	
		E1	E2
Advisability Content Aspect			
A. The comprehensive beetwen material and lesson plan as part of learning outcomes and expected final ability	1. Completeness of the material	4	4
	2. Comprehensive of the material	4	4
	3. Profoundness of the material	5	4
B. Material accuracy	4. The accuracy of concepts and definitions	4	5
	5. Principle accuracy	4	5
	6. Accuracy of Facts and Data	5	4
	7. Accuracy of examples	5	4
	8. Accuracy of exercise	5	4
	9. Accuracy of pictures, diagrams, illustrations	5	5
	10. Accuracy of Notations, symbols, and Icons	4	4
	11. Accuracy of references	4	4
C. Material Novelty	12. Comprehensive of Material to the Development of Science	4	5
	13. Novelty of pictures, diagrams, illustrations	4	5
	14. Novelty of references	4	4
	Average	**4.36**	
	Validation Criteria : Best		
Advisability Presentation Aspect			
A. Presentment Technique	1. Systematic consistency of presentation in learning activities	5	4
	2. Continuity of presentation	5	4
	3. Continuity of Scientific Approach discussion instructions	4	4
	4. The ability of exercices and discussions to improve students' critical thinking skills	4	5
B. Supporting Presentment	5.Examples of test items in each learning activity	4	5
	6. Examples of exercices in each learning activity	4	5
	7. The answer key to the practice exercices	4	5
	8. Exercices feedback	4	4
	9. Introduction	4	5
	10. Glossary	4	5
	11. References	4	4
	12. Conclusion	5	4
C. Learning Presentation	13. Students' participation	4	4

Validation Indicator	Validation Item	Score	
		E1	E2
D. Completeness of presentation	14. Part of introduction	4	4
	15. Part of content	4	4
	16. Closing section	4	4
	Average	**4.28**	
	Validation Criteria : Best		
Language Validation			
A. Brief	1. Accuracy of sentence structure	5	4
	2. Effectiveness of sentences	5	4
	3. Rigidity of terms	4	4
B. Communicative	4. Instruction Readability	5	5
	5. Accuracy in Using Language Rules	4	5
C. Dialogical and Interactive	6. Ability to motivate instructions or information	4	5
	7. Ability to encourage critical thinking	4	5
D. Comprehensive with the level of development of students	8. Comprehensive to the intellectual development of students	4	4
	9. Comprehensive to the level of emotional development	4	4
E. Coherence and integrated to way of thinking	10. Coherent and cohesiveness between learning activities	5	5
	11. Coherent and cohesiveness between paragraphs	5	4
F. Appllication of terms, symbols or icons	12. Consistency of using the term	4	4
	13. Consistency of using the symbols and icons	4	4
	Average	**4.38**	
	Validation Criteria : Best		

Table 3. displays the results of the expert validation of the worksheets. The assessment includes aspects of size, cover graphics, and appearance. While table 4 shows the results of the evaluation from users. Regarding the appearance and quality of the content.

Table 3. Results of worksheet validation from worksheet experts

Validation Indicator	Validation Item	Score	
		E3	E4
Graphic Appropriateness Aspect			
A. Worksheet Size	1. Comprehensive with the size of the worksheet contents	4	4
	Average	**4.00**	
	Validation Criteria : Good		
B. Cover Design of Worksheet	2. Color elements of the harmonious layout and clarify the function	4	4
	3. Font size of titles is more dominant and proportionate to the size of the book, the author's name	4	4
	4. The color of the book's title contrasts with the background color	5	4
	Average	**4.17**	
	Validation Criteria : Best		
C. Design Content of Worksheet	5. Placement of layout elements in consistency based on patterns	4	4
	6. The separation between paragraphs is brief	4	4
	7. Proportional print and marginal fields	4	4
	8. The two-page margins are side by side proportional.	5	5
	9. The spaces between the text and illustrations are appropriate	5	4
	10. Placement of the title of learning activities, and page numbers / folios do not interfere with the information	5	5

Validation Indicator	Validation Item	Score E3	Score E4
	Average	**4.33**	
	Validation Criteria : Best		

Table 4. Results of the limited test assessment from students

Validation Indicator	Validation Item	Score M1	M2	M3	M4	M5
A. Presentment	1. Proportional print and marginal fields	1	1	1	1	1
	2. Proportional image size	1	1	1	1	1
	3. Images can be clearly seen	1	1	1	0	1
	4. Image contrast with the background	1	1	1	1	1
	5. The intereting image	1	1	1	1	1
	6. Picture in comprehensive to the material	1	1	1	1	1
	Score Average (Percentage)			**96%**		
	Response Criteria : Positive					
B. Presentation of Materials	7. Comprehensive of the concept	1	1	1	1	1
	8. Accuracy of definition	1	1	1	1	1
	9. Accuracy of facts and data	1	1	1	1	1
	10. Nevelty of pictures, diagrams and illustrations	1	1	1	1	1
	11. Comprehensive of the questions with the material	1	1	1	1	1
	12. Ease of understanding material	1	1	1	1	1
	13. Complete worksheet components	1	1	1	1	1
	14. Comprehensive of scientific learning steps	1	1	1	1	1
	15. Brief of sentences in paragraphs	1	1	1	1	1
	16. Separation between paragraphs is clear	1	1	1	1	1
	17. Accuracy of Notations, symbols and Icons	1	1	1	1	1
	18. Comprehensive is a term with an explanation of terms	1	1	1	1	1
	19. Comprehensive with the material sample	1	1	1	1	1
	Score Average (Percentage)			**100%**		
	Response Criteria : Positive					
C. Advantages	20. Ease of understanding learning objectives	1	1	1	1	1
	21. Ease of understanding learning instructions	1	1	1	1	1
	22. Interest in reading worksheet outside the class	1	1	1	1	1
	23. Interest in solving exercises	1	1	1	1	1
	24. Interest in criticizing learning material	1	1	1	1	1
	25. Interest in connecting concepts in daily life	1	1	1	1	1
	Score Average (Percentage)			**100%**		
	Response Criteria : Positive					

In this research, a worksheet-based scientific approach has been developed by five steps of design research. The worksheet contains activities that include observing, questioning, associating, experimenting, and networking. Implementing those steps of the scientific approach is expected to reach the cognitive, affective, and psychomotor domains. The worksheet also can be used to improve students' critical thinking skills. The worksheet consists of problems to teach how students deal with problems, formulate problems in the frame, and take action according to, solve, and conclude.

The first step in this research is an exploratory study. The data obtained include (1) the analysis of the curriculum and the lesson plan required as a teaching material that can facilitate students in learning the material, especially in the study of substances or matters, classification, characteristics and changes of substances, atom theories, and tables of periodical elements, ionic and molecular compounds, (2) the main points of discussion that require the identification of a representative sample of the daily life. This requires the implementation of learning based on the scientific approach, (3) students tending to begin the study when learning takes place in class. There has been no initiative to learn independently. This makes it difficult to explore the potential of students' critical thinking. (4) lecturers used teaching materials packaged in the powerpoint media by taking examples of questions in textbooks, (5) the whole subjects in the textbook can not represent materials for a semester. Lecturers need to combine learning materials from several books and other literacies so that this is considered ineffective and inefficient in learning. (6) Worksheets related to the students' needs, materials, and characteristics are set to maximize the learning processes resulting in learning outcomes and expected learning achievements.

The worksheet development begins with collecting learning materials from various sources. The draft was compiled by taking the first to fifth week-class learning achievements. This draft consists of two parts, namely worksheet 1 and worksheet 2, each of which has two learning activities. The product preparation is developed within a structure, namely title page, author's short biography, preface, a table of contents, a list of images, introduction, learning activity 1, practice questions of scientific approach discussions, summary, formative test 1, learning activity 2, practice questions of scientific approach discussions, recaps, formative test 2, formative tests answer keys, glossary, and bibliography.

The materials are designed in such a way that they are arranged within complete, clear, communicative, and attractive platforms. The proportion that includes the cover and design is worth considering during the development. For this reason, students will remain focused on

the worksheet. By developing instructional material that appropriate to the needs will attract the attention of students (Sujatmika et al., 2019). The practice exercises are based on the first semester students' characteristics in the science education program of one universitay in Indonesia, where they took chemistry courses (course code: IPA15106) by introducing high-level questions. This problem was deliberately developed by taking into account the environment as the target. This aims to make students considerate to the environment. Students do not just know but are able to mention, explain, analyze and identify examples that exist in daily life. Scientific approach discussion activities are needed to explore the students' critical thinking skills to identify existing learning materials in the environment under the instruction of the facilitator, i.e., the lecturer. Through this instruction, learning activities will become more dialogic and interactive. Instructional materials are a tool that can help teachers and students in the learning process and in making the learning more effective (Asrizal et al., 2018).

The feasibility process for worksheet drafts is through validation by material experts and worksheet experts. The qualitative data obtained from the validators and the follow-up actions are presented in Table 5 and Table 6. There are four validators who have the qualifications of Masters in Science, Masters in Education, and Doctoral Studies. Revisions in the form of follow-up sections are based on the cases of suggestions or input as well as notes from the validators—the recommendations from the validators presented in the table below. The consultation with the validator remains continual until the worksheet is declared eligible for use in the field.

Table 5. Qualitative validation data from material experts

Validation Indicator	Validation Item	Suggestion	Continuity
Advisability Content Aspect (Material Advisable)	Accurate of References	Applying numbers of proper references	Increasing accurate references
Advisability Material Aspect (Material Accuracy)	Novelty of References	Increasing numbers of references	Increasing latest references
Advisability Presentation Aspect (Presentment Technique)	The Continuity of Scientific Approach discussion instructions	There is guidance from the instructor or lecturer related to the Scientific Approach instructions	Creating instruction procedures
Advisability Supporting Presentation Aspect (Supporting Presentment)	Conclusion	Do not write too much	The conclusion is brief and clear
Advisability Presentation Aspect (Comprehensive Presentation)	Part of introduction	The objectives of the activity include the Audience Behaviour Condition Degree (ABCD)	Creating ABCD

Table 6. Qualitative validation data from worksheet experts

Validation Indicator	Validation Item	Suggestion	Continuity
Advisability Graphical Validation Aspect (the cover design)	The font size of the title is more dominant and proportionate than that of the book, and the author's name	The title font size should be more significant than that of the others	Creating the proportional design of the cover
Advisability Graphical Validation Aspect (Content Design)	Proportionate print and marginal fields	Tables created at the center	Creating tables in the center
Advisability Graphical Validation Aspect (Content Design)	The space between the text and illustrations is appropriate	Keeping the space consistency	The space between the text and illustrations are adapted

Since it was advisable, the final step in this research was a limited assessment of a number of students in the science education program that choosed randomly. Students are interested in solving problems presented on the worksheet. Students will begin to use their critical thinking skills. The steps in the scientific approach can be used to rank the level of complexity in thinking. Worksheets can improve critical thinking skills (Hastuti et al., 2018). Students mentioned that the worksheet was suitable for use in the field. The students' recommendation aims to display the image and to make it bigger. According to the assessment, the responses of limited validation give positive responses.

CONCLUSION

The worksheet-based scientific approach can be developed from 5 steps which are a simplification of the Borg and Gall development model, namely exploratory study, product design, expert validation and revision, limited and revised testing, and mind field testing and final product. The validation experts state that the products have an average material advisability score of 4.34 along with its best criteria and the worksheet advisability average of 4.17 along with its best standards. The random assessment from the number of students has obtained an average score of 98.67% (positive response). Based on the results, worksheets based on a scientific approach are advisable for students studying chemistry course in the science education program.

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