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*Research Article*

# Developing STEM students' worksheet to improve students' creative thinking ability

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**Abstract:** Changes in the learning paradigm that prioritizes the optimization of creative thinking skills require a lot of consistent innovation and development. This study aims to develop students' worksheets based on STEM on viruses. This development research uses a 4D model by Thiagarajan. The instruments used in this study included interview sheets, validation sheets for content experts and media experts, questionnaires for biology teacher responses, and questionnaires for student responses, as well as tests. Product effectiveness on students' creative thinking skills was carried out using a pretest-posttest design and analyzed using the N-gain calculation. The results showed that the STEM-based students' worksheets on the Virus material that was developed received an assessment of 98% from content experts and 87% from media experts with very valid criteria. The responses of teachers and students were 93.3% and 90% respectively with very practical criteria. The developed STEM-based students' worksheets are also effective in increasing students' creative thinking skills by 0.75 with moderate criteria. These results indicate that STEM-based students' worksheets are appropriate for use in learning to improve students' creative thinking abilities.

**Keywords:** Creative thinking ability; STEM; students' worksheet

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## 1. Introduction

Currently, the shift in the learning paradigm that occurs from traditional or conventional ways to innovative learning (Kencana et al., 2020; Maniotes & Kuhlthau, 2014; Osborne, 2012) that fosters more thinking power is said to be in line with educational reform (Shanmugavelu et al., 2020). One form of education reform is carried out using a learning approach that can assist teachers in creating experts through the science, technology, engineering, and mathematics (STEM) approach (Kencana et al., 2020; Santangelo et al., 2021; Teo et al., 2021). Collaboration in the STEM learning process is believed to be able to help students collect and analyze contextual problems around them in order to find the best solution (Abosalem, 2016; Davidsen et al., 2020; Loes et al., 2018). Furthermore, students are faced with a learning atmosphere that connects a problem with other problems (Tan et al., 2019). The STEM approach develops when it is associated with the surrounding environment, so that a learning is realized that presents contextual problems experienced by students in everyday life (Kennedy & Odell, 2014; Teo et al., 2021). It means that through the STEM approach students are not just memorizing concepts, but rather how students understand science concepts and apply them in everyday life (English, 2016; Lin, 2011). STEM-based learning is implemented by deepening concepts and contextual problems with inquiry-based learning models (Schallert et al., 2021; Thuneberg et al., 2018). Solving problems through cross-disciplinary studies is believed

to be able to shape the character of students to be able to recognize problems comprehensively (Tan et al., 2019; Teo et al., 2021). On the other hand, the concept or knowledge possessed acts as capital in creating or designing solutions based on mathematical data calculations in solving a problem so that students become easier (Fujii, 2016; Sahin et al., 2014). However, teachers need to design STEM-based learning with learning tools and steps that provide collaboration spaces for students.

One of the tools needed in STEM learning is student worksheets (Lestari et al., 2018; Sutarto et al., 2021). Student worksheet development needs to be done as part of STEM learning planning (Felder & Brent, 2016; Schallert et al., 2021). Several studies state that the development of STEM learning tools needs to be done a lot (Linh et al., 2019; Schallert et al., 2021; Siew & Ambo, 2018). Apart from the differences in contextual issues raised, the integration of learning models (Wang et al., 2021), innovations (Widya et al., 2019), and specific student characteristics (Pollard et al., 2018; Sahin et al., 2014) are some of the reasons why the development of STEM learning tools needs to be done. The availability of devices as a means to assist in facilitating teaching and learning activities so that effective interactions are formed between students and teachers (Sahin et al., 2014; Siew et al., 2016). The student worksheet contains instructions and steps for solving problems that have been defined in learning (Sutarto et al., 2021).

The results of interviews with Biology teachers as class X teachers at Islamic Senior High School/*Madrasah 'Aliyah Negeri* (MAN) 2 of Tapanuli Tengah show that there are still many subjects that have not used STEM-based student worksheets, including biology subjects. The results of the interviews also show that the level of students' creative thinking is still relatively low. It can be seen from students who have not been able to give opinions or ideas and are embarrassed to express their opinions during the teaching and learning process. In addition, the student worksheets used do not meet the criteria for good and correct preparation and do not present contextual materials related to science, technology, engineering, and mathematics which have implications for increasing students' creative thinking. Council (2012); Felder and Brent (2016); Sada et al (2016) revealed that the problems in the classroom were still centered on the teacher and teachers had not fully used student worksheets. It can be seen from the problem solving scientific literacy skills in following student learning in the classroom. Difficulties in the classroom regarding virus material, i.e. that students do not understand the virus material presented in the textbooks at school (Bahri et al., 2016).

Many research has been done on the development of STEM-based student worksheets (Lestari et al., 2018; Putri et al., 2022; Sutarto et al., 2021). However, the development of STEM-based student worksheets is still focused on other materials, such as ecosystems (Ngabekti et al., 2019; Wahyuni et al., 2022) and environmental change (Simatupang et al., 2020), while the development of student worksheets on virus material is still small. This study aims to develop STEM-based student work-sheets to improve students' creative thinking skills on viruses in class X MAN 2 Tapanuli Tengah.

## 2. Materials and Methods

This development research uses a 4D model by Thiagarajan (Thiagarajan et al., 1976). This research and development model is used to develop a product by validating the products to be used in the educational environment.

The definition stage is carried out by gathering information about what learning tools need to be developed based on the process of needs analysis and situation analysis. In this study the device developed was in the form of a student worksheet. The design stage is carried out by developing materials related to viruses and their problems in everyday life. At this stage the design of student worksheets is based on a science, technology, engineering, and mathematics (STEM) based approach. The development stage in this study produced student worksheets that had been validated by content experts and media experts, so that they were ready to be tested by students. The final stage of development is dissemination of products that have been tested to small groups in class. This stage is an important stage before it is produced in large quantities.

The instruments used in this study were (1) interview sheets, to collect data in the form of information we need from a teacher; (2) validation sheet, to collect data by providing an assessment of the product to be developed and given to content experts and media experts to validate existing products. The data obtained in this study were in the form of quantitative data (assessment scores of material experts, media experts, teacher responses and student responses) and qualitative data (in the form of responses and suggestions given by expert validators regarding the student worksheet that had been developed). Validity analysis is based on expert validation results. This validation analysis is carried out using the Formula (1). The validation results are then analyzed with the validation criteria in Table 1 (Riduwan, 2013).

$$Percentage\ (\%) = \frac{Score\ obtained}{Maximum\ score} x\ 100\% \quad (1)$$

**Table 1.** Validation criteria

| Percentage (%) | Criteria |
|---|---|
| 80.00 – 100 | Very valid |
| 60.00 – 79.99 | Valid |
| 50.00 – 59.99 | Quite valid |
| 00.00 – 49.99 | Invalid |

Product practicality is seen based on student and teacher response questionnaires, with assessments using the Guttmann calculation scale (Table 2) refers to Abdi (2010).

**Table 2.** Guttman scale practicality criteria

| Percentage (%) | Criteria |
|---|---|
| 81 – 100 | Very practical |
| 61 – 80 | Practical |
| 41 – 60 | Quite practical |
| 21 – 40 | Impractical |
| 0 – 20 | Very impractical |

Effectiveness analysis was seen based on the results of the posttest and pretest of the students who had done it. Assessment of effectiveness using the N-gain Formula (2) and criteria as described in Table 3.

$$N - gain(\%) = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score} x\ 100\% \quad (2)$$

**Table 3.** Normalized N-gain criteria

| N-gain Score | Category | Criteria |
|---|---|---|
| < 0.3 | Low | Uneffective |
| 0.3 ≤ x ≤ 0.7 | Moderate | Quite effective |
| > 0.7 | High | Effective |

## 3. Results

Preliminary assessment has been done before product development. According to the development step (Thiagarajan et al., 1976), this stage is known as define. This activity is carried out by conducting interviews and observations on learning with stakeholders such as biology teachers and students as also. The results of the interviews show some information, i.e. (1) the curriculum used in schools is the 2013 curriculum, (2) the current student worksheets have not been able to present the main objectives in learning such as basic competencies, indicators, and learning steps, (3) the student worksheets used at school in their preparation also do not meet the requirements for good and correct media,

(4) the student worksheets used are not attractive, tend to contain only cognitive questions, and do not encourage students to generate new opinions or ideas in during the learning process on viral material, so it does not foster creative thinking skills in students.

The learning challenges about virus is that students do not understand the virus material presented in the textbook. One of the determinants of this condition is that learning is not yet based on contextual problems related to viruses in everyday life, so that students tend to be in a passive position in learning. In addition, the references used in learning are limited, so students do not have enough space to develop their thinking skills. The results of this assessment refer to a policy that requires innovation in teaching viruses using STEM-based student worksheets to improve students' creative thinking.

The design stage is carried out by making the initial product which consists of several components. Components contained in the student worksheet include content sections and supporting sections. The content section consists of core competencies and basic competencies in viral material, contextual problems, and problem in-depth study, exploration of ideas and solutions, and cognitive questions. On the other hand, the supporting part consists of a cover, preface, table of contents, guidance, and bibliography. At the develop stage, validation of the product is carried out through a series of validations by content experts, constructors, and subject teachers, and revisions have been made, so the student worksheet with the STEM approach to viral material has been declared valid and suitable for learning activities in schools.

**Table 4.** Assessment results by content experts

| Validation aspect | Percentage (%) | Criteria |
|---|---|---|
| Material feasibility | 96 | Very valid |
| STEM component | 100 | Very valid |
| Language | 100 | Very valid |

**Table 5.** Revision note from content expert validator

| Advices | Before | After |
|---|---|---|
| Enrich references on student worksheets | Student worksheets are written with limited references | Enriching the product with a new references like printed books, journal articles, and online news links |
| Adding visual images of viruses in the discourse section | The variety of viruses has been written in the form of sentences within paragraphs. The narrative also writes the history of development from the beginning it was discovered | The variety of viruses is not only written in the form of sentences but also equipped with illustrations of the types of viruses that have been found |
| Fixed incorrect vocabulary | There were several writing errors in the worksheet, such as general information, activity guides, and several other important sections | Improvements were made by rewriting incorrect vocabulary and proofreading to ensure the quality of the reading produced |

The results of product validation by the content validator (Table 4) show that the STEM component and linguistic aspects have a percentage score of 100%. These results indicate that the product that has been developed is classified as very valid, so it can be used in the learning process. Furthermore, the validator provides notes as material for product improvement (Table 5).

Student worksheets have been validated by media experts. The results of the worksheet assessment show that the score obtained is 87% so it is categorized as very valid as described in Table 6. Furthermore, these results also show that the worksheet with the STEM approach to virus material is feasible and can be used in learning. Suggestions for improving the expert validator (Table 7) include strengthening the integration of the STEM approach in student worksheets.

**Table 6.** Results of student worksheet validation by media experts

| Validation aspect | Percentage (%) | Criteria |
|---|---|---|
| Component presentation | 87 | Very valid |
| STEM component | 100 | Very valid |
| Worksheet design | 75 | Valid |

**Table 7.** Revision note from media expert validator

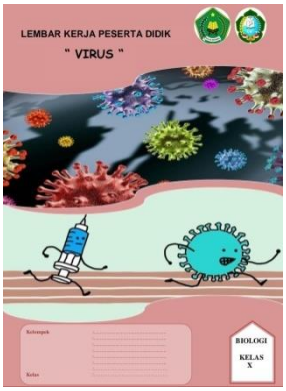
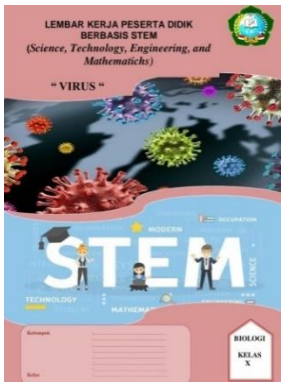
| Advices | Before | After |
|---|---|---|
| Added elements that represent STEM on the cover |  |  |
| Provide examples of posters at the product design stage |  |  |

**Table 8.** Biology teacher assessment results

| Aspects | Percentage (%) | Criteria |
|---|---|---|
| Lay outing | 100 | Very practical |
| Content eligibility | 100 | Very practical |
| STEM component | 80 | Practical |

The results of the biology teacher's assessment stated that the STEM-based worksheet for virus material was in the very practical criteria with a score of 100% for the feasibility aspects of layout and content (Table 8). This shows that STEM-based worksheets are very practical and appropriate for use in biology learning. However, the teacher recommends clarifying the instructions for using worksheets for students. These improvements need to be made before dissemination so students can understand the use of worksheets properly.

The results of the percentage of student responses stated that STEM-based worksheets on virus material were in very practical criteria with percentages above 80% for all three aspects of the assessment. These results indicate that the developed worksheet is feasible and can be used in biology learning, especially virus material

The dissemination stage was carried out in the tenth-grade science involving 35 students of MAN 2 Tapanuli Tengah. This deployment is intended to obtain the effectiveness of products that have been designed for the biology learning process, especially on Virus material. The effectiveness of LKS can be seen from the achievement of learning imple-

mentation in the form of individual completeness scores and observations of student activities in ongoing learning. The data analysis shows that the student's N-gain score is 0.75 with a practicality of 90.50% (Table 9).

**Table 9.** N-gain score and product practicality

| | Score | Criteria |
|---|---|---|
| N-gain | 0.75 | High |
| Practicality | 90.50 | High |

## 4. Discussion

The increase in posttest scores from the pretest indicates that STEM-based worksheets are effective in increasing students' creative thinking abilities. Furthermore, students also find it easy to use worksheets in the learning process marked by students' practicality scores while studying with worksheets. Some researchers believe that practicality and a relatively high N-gain score cannot be separated from the innovations developed in the products produced (Syafii & Yasin, 2013; Tan et al., 2019; West, 2015), in this case what is meant is the integration of STEM in learning (Honey et al., 2014; Schallert et al., 2021).

The science aspect in the worksheet is developed by selecting contextual problems related to viruses in everyday life (Kennedy & Odell, 2014). In this case, students learn the function, definition, and characterization of viruses from the context of the problems they face (Hua & Shaw, 2020). Furthermore, STEM-based worksheets place problems as a stimulus for student dialogue and discussion which provides space for students to study problems more deeply in order to find the best solution (Haavind, 2019; Zulkarnaen et al., 2017). On the other hand, STEM-based worksheets are also equipped with trigger questions such as why diseases caused by viruses spread so easily? The answers to these trigger questions require a deep understanding of viruses as part of science (Jandrić, 2020; Kuhn, 2011; Miharja et al., 2019; Wood, 2018).

The technological aspect in the worksheet refers to how students can design vaccines as a solution to controlling the spread of the virus (Larson, 2018). For example, what is the right technology to maintain or extend the shelf life without reducing the quality of the vaccines produced? (Lin et al., 2020; Rothan & Byrareddy, 2020). Furthermore, is there a simpler technology to make vaccines with new innovations that are more feasible? (Larson, 2018; Mascola & Fauci, 2020; Schlake et al., 2012). These ideas are closely intertwined with vaccine engineering design and mathematical calculations in the idea development process so that studying viruses by departing from contextual problems can be approached with a STEM perspective in predicting and determining the best solution (Tan et al., 2019).

The results of this study indicate that efforts to improve creative thinking skills can be done by providing learning media that facilitate students' multidisciplinary thinking (Kambeyo & Csapo, 2018; Pressman, 2019). However, some researchers realize that in order to provide more in-depth results to students, it needs to be done through systematic and continuous efforts (Opara & Oguzor, 2011; Rahman, 2019). STEM learning resonance contextually needs to be carried out continuously so that students get used to thinking systematically, as well as linking these problems to various relevant possible solutions (Radulović & Stančić, 2017).

## 5. Conclusions

The developing of STEM-based worksheets improves students' creative thinking skills which are classified as very valid. Furthermore, the resulting product is also very effective in improving creative thinking skills based on the N-gain score.

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