



Research Article

Developing biology students' worksheet based on STEAM to empower science process skills



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ABSTRACT

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Students' worksheets, as learning material, is important to achieve learning outcomes. This study aimed to develop students' worksheet, based on STEAM (Science, Technology, Engineering, Art, and Mathematics), on ecosystem topics to empower students' science process skills. The Research and Development used 4D model by Thiagarajan. Students' worksheet validity was determined by conducting expert appraisal consisting of instructional review (material and learning expert) and technical review (biology teacher). The product trial was carried out by testing the science process skills of tenth graders. The students' science process skills were measured using pre-test and post-test, which then were analyzed using N-gain calculation. The results showed that the students' worksheet based on STEAM was categorized as feasible (material expert) and highly feasible (learning expert and teacher). The N-gain score of students' science process skills after using student worksheet based on STEAM was 0.5 which categorized as medium. It can be concluded that the students' worksheet developed is feasible and able to empower the students' science process skills.



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INTRODUCTION

Students' worksheets, written teaching materials, play an important role as teacher agents in effective teaching practices to achieve learning outcomes (Lee, 2014; Nyamupangedengu & Lelliott, 2012; Ransom & Manning, 2013). Students' worksheets train students' independence in learning and are designed according to learning competencies (Sari, Selisne, & Ramli, 2019). Students' worksheets play a role in increasing understanding in to form basic abilities that are appropriate to the learning indicators that must be achieved.

Students' worksheets are useful for practicing independence, literacy, creativity, and student understanding (Febriani, Sudomo, & Setianingsih, 2017; Kolomuc, Ozmen, Metin, & Acisli, 2012; Sari et al., 2019). Students' worksheets determine students' interest in reading and writing, allow students to make feedback in learning activities, accommodate student difficulties, and create flexible learning activities for student development. Saputro, Setiawan, and Saragih (2019) stated that students' worksheets are also as a stimulus in learning that will be presented in writing so that it is necessary to consider the criteria of graphic media as visual media to attract students' attention.

Students' worksheets generally consist of information, problems, instructions, and guiding questions (Farida, Supriadi, & Kurniawati, 2019). Ideal student worksheets must-have requirements in the form of validity, practicality, and effectiveness (Ayva, 2012; Farida et al., 2019; Febriani et al., 2017; Kibar & Ayas, 2010; Saputro et al., 2019; Subhan & Oktolita, 2018). The validity of student worksheets can be seen from the scientific arrangement and each component of the worksheet is interrelated. The practicality of the worksheet in question is if the worksheet is easy to use by students. And the effectiveness of worksheets means that the worksheets meet the learning objectives (Sari et al., 2019).

Student worksheets have been used in teaching practice for a long time. Hence, student worksheets must also be dynamic following current learning demands. Today's learning must be able to provide students with the skills and knowledge needed to develop in the 21st-Century (Darling-hammond, 2014; Greenstein, 2012; Osborne, 2013). These skills include creativity and critical thinking skills, curiosity, resilience, problem-solving, reason, collaboration and self-confidence that can be accommodated with STEAM education (Allina, 2018; Conradty & Bogner, 2019; Jacques, Cian, Herro, & Quigley, 2019; Liao, Motter, & Patton, 2016) which is important in science process skills. STEAM stands for Science, Technology, Engineering, Art, and Mathematics - a powerful combination of topics and techniques for educating students (Conradty & Bogner, 2019; Yoon & Baek, 2018). STEAM learning will develop innovative mindsets and the ability to solve problems, ensuring that students become creators of technology, not just passive consumers. STEAM aims to strengthen the foundation of STEM by helping students improve their critical thinking skills and recognize the intersection of art, science, technology, engineering, and mathematics (Conradty & Bogner, 2019). STEAM-based learning trains students to explore new and creative ways of solving problems, displaying data, innovating, and connecting various fields (Dyer, 2019; Gates, 2017; Kelton & Saraniero, 2018). Art subjects and STEMs naturally complement each other and provide information to each other, so that the application of the STEAM principle into education allows for more understanding, innovation, and cohesive education in the classroom (Conradty & Bogner, 2019). Thus the designing of STEAM-based students' worksheets needs to be developed to support effective learning.

However, the development of STEAM-based students' worksheets is very rarely done, especially in schools in Indonesia. Some research related to the development of students' worksheets is still based on STEM learning (Santoso & Mosik, 2019; Sari et al., 2019; Sulistiyowati, Abdurrahman, & Jalmo, 2018). Even worse, many schools rely solely on student worksheets from textbooks, rather than the development of the teachers themselves. This fact is also supported by the results of observations made at SMAN (*Sekolah Menengah Atas Negeri* – State Senior High School) 1 of Berastagi in North Sumatera, Indonesia. Based on observations at SMAN 1 of Berastagi, students' worksheets used in biology learning were still taken from textbooks. This worksheet does not accommodate activities that encourage students to investigate and understand learning material based on scientific attitudes. As a result, students only learn by memorizing theory and transferring the contents of textbooks to students' worksheets. On the other hand, the education curriculum in Indonesia requires all learning activities to be centered on students and accommodate students to be able to have skills in the 21st-Century. Thus, as an effort by teachers to meet the demands of the 21st-Century challenges, it is necessary to try to develop or redesign relatable worksheets.

Furthermore, student worksheets based on STEAM education in this study are expected to contribute to training students in empowering their science process skills. Science process skills can be measured by looking at students' ability to make observations, ask questions, conduct experiments, make associations, and communicate results (Gultepe, 2016; Hodosyová, Útla, MonikaVanyová, Vnuková, & Lapitková, 2015; Karamustafaoğlu, 2011). Some researchers stated that by using a proper worksheet, the student can enhance their science process skills (Bolat, Türk, Turna, & Altınbaş, 2014; Durmaz & Mutlu, 2017; Fajriyanti, Ernawati, & Sujatmika, 2018; Septiani & Rustaman, 2017; Subhan & Oktolita, 2018). For that reason, this study aimed to develop students' worksheets, based on Science, Technology, Engineering, Art, and Mathematics (STEAM), on ecosystem topics to empower students' science process skills.

METHOD

The Research and Development used 4D model by Thiagarajan, Semmel, and Semmel (1974) with restrictions on three phases, namely (1) define, (2) design, and (3) development. The dissemination phase was not regulated since the research objectives have been obtained to develop a valid, practical, and effective students' worksheet to empower students' science process skills. At the define phase, the observation sheet was used as an instrument to analyze student worksheets and their suitability with the syllabus at SMAN 1 Berastagi. Furthermore, at the design phase, students' worksheet design was made based on STEAM education and learning objectives on the ecosystem topic. Then in the development phase, instruments were used are validation sheets (with Likert scale) and science process skills tests.

The developed students' worksheets based on STEAM were validated by expert appraisal consisting of instructional review (appropriateness, effectiveness, feasibility) and technical review (media and content). The instructional review was carried out by material experts and learning experts, while the technical review was conducted by a teacher in school. The science process skills test, which consists of 25 multiple choice questions, was used to measure the effectiveness of the worksheet by conducted a product trial. The product trial was carried out by testing the large group of tenth graders in SMAN 1 of Berastagi. The indicators measured of science process skills were limited only five skills, namely: (1) making an observation, (2) asking a question, (3) conducting an experiment, (4) making association, and (5) communicating (Gultepe, 2016; Hodosyová et al., 2015; Karamustafaoğlu, 2011). The validation data from the instructional and technical review were analyzed descriptively by calculating the average scores (Formula 1) and categorizing based on categorization presented in Table 1 (Farida et al., 2019). The results of students' process skills tests, pretest and post-test scores, were analyzed by calculating the N-gain score (Formula 2) and categorized based on categorization presented in Table 2 (Febriani et al., 2017).

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad (1)$$

where \bar{x} = average total validity, x_i = score of aspect-I, and n = number of aspect-i.

Table 1. Categories of validation result

Score Interval	Category
$0.0 \leq \bar{x} < 1.6$	Not feasible
$1.6 \leq \bar{x} < 2.2$	Less feasible
$2.2 \leq \bar{x} < 2.8$	Fairly feasible
$2.8 \leq \bar{x} < 3.4$	Feasible
$3.4 \leq \bar{x} < 4.0$	Highly feasible

$$(g) = \frac{\text{posttest score} - \text{pretest score}}{\text{maximal score} - \text{minimal score}} \quad (2)$$

where (g) = N-gain score.

Table 2. Categories of N-gain score

The value of the (g)	Category
$(g) > 0,7$	High
$0,3 \leq (g) \leq 0,7$	Medium
$(g) < 0,3$	Low

RESULTS AND DISCUSSION

Define phase

The analysis results of students' worksheets at SMAN 1 of Berastagi in the define phase are known as follows: (1) Schools use worksheets from publishers which consist of titles, subtitles, core competencies, basic competencies, material summaries, and tests (containing multiple-choice and essays questions). (2) Student worksheets have not emphasized the scientific approach following the curriculum in Indonesia. This worksheet does not accommodate activities that encourage students to study and understand learning material based on scientific attitudes. (3) Based on the form of students' worksheets used, students only learn by memorizing theory and transferring the contents of textbooks to students' worksheets. (4) Learning objectives and assessments that are not yet fully present in worksheets that are used in schools. Based on the define phase

result, the worksheet used in SMAN 1 of Berastagi needs to be redesign because it does not accommodate activities that encourage student-centered learning. Today's learning must be able to equip students with skills to face challenges in the 21st-Century (Binkley et al., 2014; Haviz, Karomah, Delfita, Umar, & Maris, 2018; Turiman, Omar, Daud, & Osman, 2012). The skills needed include problem-solving skills (Binkley et al., 2014; Liao et al., 2016), critical thinking (Liao et al., 2016; Maryuningsih, Hidayat, Riandi, & Rustaman, 2019) and science process skills (Haviz et al., 2018; Turiman et al., 2012). A teacher must be able to create learning strategies that can empower these skills, including in making students' worksheets which are one of the main learning materials for creating effective learning.

Design phase

Based on define phase results, the students' worksheet designs based on STEAM education were made. The main problem being studied is environmental issues on the ecosystems topic. The cover and the content of students' worksheet based on STEAM are presented in Figure 1.



Figure 1. The cover (a) and the content (b) of students' worksheet. In the content consists of mind map, foreword, instruction, core & basic competencies, material summaries, indicator & learning objectives, **science** part, **technology** part, **engineering** part, **art** part, **mathematics** part, and references.

The **science** part of this worksheet is an experimental activity that will train students to build their scientific attitude. In the developing worksheet, the experimental activity is related to the effect of light intensity on the ecosystem (see Figure 2). At the end of the science part there is an assessment column for student work.



Figure 2. In the **science** part, students are asked to do the effect of light intensity on the ecosystem by comparing water ecosystems covered with carbon paper with those without carbon paper (a). Next students are asked to answer questions related to the impact of a cover (carbon paper) on the biotic and abiotic components in the aquatic ecosystem (b).

The **technology** part of this worksheet is in the form of utilizing technology that can be used to gather information as an effort to solve environmental problems, also to stimulate students' creativity and critical thinking. This section presents discourse related to technology in ecosystems, including eco-hydrology, phytoremediation and phyto-technology. Students are asked to provide feedback related to these technologies. Then, the **engineering** part of this worksheet in the form of activities gave rise to a new concept of 'Class Park' which would be one of the solutions to environmental problems in the form of air pollution in the ecosystem. In this section students are asked to make a project in the form of a classroom garden design and a good carbon cycle for a simple ecosystem that can reduce pollutants in the air by utilizing phytoremediation plants (see Figure 3). At the end of both, technology and engineering part, there is an assessment column for student work.



Figure 3. The **engineering** part of students' worksheet which ask student to design a project related to class park.

Furthermore the **art** part of the worksheet is inviting students to beautify and promote garden engineering for a better ecosystem. In this part students are asked to explain how the beauty and usefulness of the classroom garden that has been designed with the group. And finally **mathematics** part on the worksheet is the ability of students to make formulations, use formulas, and even interpret data in a mathematical approach to solve problems related to ecosystems. In this section students are asked to solve problems related to the efficiency of the ability to absorb anti-pollutant plants in an ecosystem. This part is individual work.

Development phase

In the development phase, the developed students' worksheets based on STEAM were validated by expert appraisal consisting of instructional and technical review. The result of the instructional review which carried out by material experts and learning experts are presented in Table 3 and Table 4, while the technical review which conducted by a teacher in school are explained in Table 5. The expert appraisal results, both instructional review and technical review provide the feasible and highly feasible categories for developed students' worksheets. The results of the instructional review by material expert stated that the product categorizes as feasible (3.2), whereas the learning expert declared that the product was highly feasible to use (3.7). However, there is a slight revision by the expert material, which is adding further exploration of the topic in the worksheet. Not only ecosystem topics in a summary but also the supporting information related to another topic that correlated with it. The addition of information in the form of this reading will support the level of student exploration as well as his skills in literacy on learning topics. According to Long and Davis (2017) STEAM education, supporting students' scientific literacy. Literacy is an action with common components that are

embedded in how we consume and share information, as such, it is naturally a part of STEAM. This scientific literacy is the basis of developing students' science process skills (Ayva, 2012; Guevera, 2015; Handayani, Adisyahputra, & Indrayanti, 2018; Turiman et al., 2012).

Table 3. Validation result of material expert

No.	Components	Score
1.	Completeness of material	3
2.	The extent of the material	3
3.	Material depth	3
4.	The accuracy of facts and data	3
5.	The accuracy of examples and cases	3
6.	Accuracy of references	3
7.	Encourage curiosity	4
8.	Systematic consistency of presentation in worksheet	3
9.	Coherency of material conceptual	3
10.	Introduction in worksheet	3
11.	Bibliography of worksheet	3
12.	Student involvement	4
13.	Science aspect in worksheet	3
14.	Technology aspect in worksheet	4
15.	Engineering aspect in worksheet	3
16.	Arts aspect in worksheet	4
17.	Mathematics aspect in worksheet	4
Average score		3.2 (feasible)

In addition, the learning experts responded that in the engineering activities on the worksheets were good for students' learning. In this part, students were invited to reconstruct their class park using antipollution plants. The learning expert has appreciated the concept of these activities. In this class park design activity students are trained to develop their innovation and creativity. Correspondingly, STEAM education helps students from all backgrounds develop innovative mindsets (Dyer, 2019; Liao et al., 2016; Long & Davis, 2017; Rolling, 2016) with the ability to create and think creatively (Conradty & Bogner, 2019; Costantino, 2018; Perignat & Katz-Buonincontro, 2019; Rolling, 2016; Yoon & Baek, 2018). This ability is needed by students to be able to develop their science process skills (Candrasekaran, 2014; Mora, Signes-Pont, Fuster-Guilló, & Pertegal-Felices, 2020).

Table 4. Validation result of learning expert

No.	Components	Score
1.	Completeness of material	4
2.	The extent of the material	3
3.	Material depth	4
4.	The accuracy of drawings, diagrams, and illustrations	4
5.	Use examples and cases in Indonesia	4
6.	Accuracy of references	4
7.	Encourage curiosity	4
8.	The display of worksheet enticing and in accordance with the development of student	4
9.	Systematic consistency of presentation in worksheet	3
10.	Coherency of material conceptual	3
11.	Motivation for each learning in the student worksheet.	4
12.	Introduction in worksheet	4
13.	Bibliography of worksheet	4
14.	Student involvement	3
15.	Science aspect in worksheet	4
16.	Technology aspect in worksheet	4
17.	Engineering aspect in worksheet	4
18.	Arts aspect in worksheet	3
19.	Mathematics aspect in worksheet	4
Average score		3.7 (highly feasible)

The biology teacher who conducted a technical review said that STEAM-based student worksheets are highly feasible to use with a score of 3.5 (see Table 5). The teacher's feedback is to eliminate one activity in the technology part on the worksheet (the PCR technology) because the topic has not been received by students in grade 10. The teacher adds that the art part is still less visible, even though the score is given 3. Perignat and Katz-Buonincontro (2019) stated that the art part of STEAM plays a big role in its development. STEAM is the development of the STEM principle by integrating these principles in and through art (Hunter-Doniger & Sydow,

2016; Perignat & Katz-Buonincontro, 2019; Rolling, 2016). STEAM takes STEM to the next level because it allows students to connect their learning in these critical fields together with art practices, elements, design principles, and standards to provide all of their learning palettes (Conradty & Bogner, 2019; Hunter-Doniger & Sydow, 2016). STEAM removes boundaries and replaces them with criticisms and innovation (Grant & Patterson, 2016; Kelton & Saraniero, 2018; Liao et al., 2016).

Table 5. Validation result of technical review (teacher)

No.	Components	Validation Score
1.	Systematic consistency of presentation in worksheet	3
2.	Coherency of material conceptual	3
3.	Introduction in worksheet	4
4.	Bibliography of worksheet	4
5.	Student involvement	3
6.	Understanding of messages or information	3
7.	The ability to motivate students	3
8.	Encourage critical thinking	4
9.	Conformity with the level of intellectual development of students	4
10.	Grammar accuracy	3
11..	Science aspect in worksheet	4
12.	Technology aspect in worksheet	4
13.	Engineering aspect in worksheet	4
14.	Arts aspect in worksheet	3
15.	Mathematics aspect in worksheet	4
Average score		3.5 (highly feasible)

The product trial results in tenth graders show that the N-gain score of students' science process skills is categorized as a medium category with a score of 0.5 (Table 6). Indicators of science process skills with the highest improvement is observation skill, while the lowest is conducting experiment skill. This can happen because students are not accustomed to doing learning activities that are integrated with STEAM. And based on observations showing that this is the first time this school uses the STEAM approach in learning activities. Thus students are still not accustomed to carrying out scientific activities, hence their science process skills (in this case conducting experiment skill) are still not properly empowered.

Table 6. The result of students' science process skill test

Indicator	Pretest	Posttest	Difference	N-gain
Making an observation	26.2	31.8	5.6	0.5 (medium)
Asking a question	26.4	31.4	5	
Conducting an experiment	26.2	30	3.8	
Making association	27	31.6	4.6	
Communicating	26.4	30.8	4.4	

However, in general it can be said that the results of the development of STEAM-based students' worksheets can trigger an improvement in students' science process skills. The improvement in students' science process skills (shown in Table 6) confirms the contribution of STEAM education in each student activity process. The experimental activity in the science part of the worksheet invites students to be able to identify changes in experimental variables, interpret possibilities that will occur in experiments, and determine the components that influence the ecosystem. With this activity, students' abilities in observing, experimenting, and asking questions are well-honed (Jacques et al., 2019; Thuneberg, Salmi, & Bogner, 2018). Activities in the technology part of linking new information affect the ability of students to observe, associate, and communicate (Ayva, 2012; Liao et al., 2016). In this section students are directed to determine their ideas in designing class parks affecting the ability of students to observe, experiment, collaborate and communicate.

The art part of the worksheet invites students' creativity to the beauty and usefulness aspects of the class park design created. This activity plays a role in bringing out the power of innovation and student creativity (Conradty & Bogner, 2019; Grant & Patterson, 2016; Perignat & Katz-Buonincontro, 2019; Rolling, 2016; Wandari, Wijaya, & Agustin, 2018). Also, the mathematics part that instructs students to use formulas or even to interpret data can affect student skills, especially the skills of making associations and communicating (Ayva, 2012; Conradty & Bogner, 2019; Thuneberg et al., 2018). Thus, the research findings show that the development of students' worksheets based on STEAM can initiate an improvement in students' science process skills. Therefore, this development product are expected to be disseminated and used further in biology learning, especially on ecosystem topic.

CONCLUSION

The research findings showed that the students' worksheet based on STEAM was categorized as feasible (material expert) and highly feasible (learning expert and teacher) to use. The N-gain score of students' science process skills after using student worksheet based on STEAM was 0.5 which categorized as medium. It can be concluded that the students' worksheet developed is feasible and able to empower the students' science process skills. Therefore, students' worksheets based on STEAM are expected to be disseminated and used further in biology learning, especially on ecosystem topic.

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