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Research Article

Developing STEM-based TGT learning model to improve students' process skills

Faizah Firdaus [a,1], Wachju Subchan [a,2], Erlia Narulita [a,3,*]
[a] Magister of Science Education, Faculty of Teacher Training and Education, University of Jember, Jl. Kalimantan No.37, Krajan Timur, Sumbersari, Kec. Sumbersari, Kabupaten Jember, East Java 68121, Indonesia
[1] faizahfirdaus70@gmail.com; [2] wsubchan@gmail.com; [3] erlia.fkip@unej.ac.id*
* Corresponding author

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ABSTRACT

Strengthening STEM-oriented learning is necessary for 21st century, so the development of appropriate learning models must be carried out. The aimed to of this study were analized validity, effectiveness, and practicality of STEM-based Team Games and Tournament (TGT) learning model towards the students' science process skills. This research was research and development (RnD) with a 4-D development namely; Defining, Designing, Developing, and Disseminating. The study involved 2 experts as validators, 2 teachers as user, and 112 students in small-scale tests, large-scale tests, and distribution tests in SMA. The research was done until the stage of disseminating and produced. The results showed the validity value of 83% was categorized as very valid, the effectiveness score of 83.9% was categorized as good, and the practicality score was 87.5%, so that it was declared valid, effective, and practical to improve the science process skills. Therefore, it is recommended to be applied in schools.

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INTRODUCTION

The quality of education significantly affects the betterment of a country. Entering the 21st century, the education in Indonesia faces a complex challenge which required individual to have skills, knowledge, and mastery in the field of technology, media, and information (Afandi, Sajidan, Akhyar, & Suryani, 2019). Preparing qualified graduates who are able to compete globally and master the development of technology has become one of the essential things for many people and the country's future (Kanematsu, H., & Barry, 2016).

The efforts to fulfill the 21st educational standards and preparing the students who are able to compete in a global working world can be made through the innovation of integrating STEM approach in learning. Science and technology start to arise and growing up in order to meet the needs of human life by any research and experiments (Utomo, Novenda, Singgih, & Narulita, 2019). Kelley & Knowles, (2016) defined STEM as an approach to teaching two or more subjects that are related to the authentic practice so that can improve the students' learning interest. STEM consists of four disciplines that are science, mathematics, engineering, and technology that cannot be implemented separately. Afriana et al., (2016) stated that science learning needs mathematics as the tools to process data and technology as well as scientific engineering which are the application of science itself.

Zorlu & Zorlu (2017); Afriana et al., (2016) stated that STEM approach in learning is able to produce meaningful learning for students through the integration of knowledge, concept, and skills systematically, and also it can make the students able to be better at solving problems. STEM-based education can be integrated with various learning models and methods. It is due to its integrative characteristics that enable various learning models and methods to be used to support its implementation in the classroom learning process (Septiani & Rustaman, 2017).

One of the learning models that can support STEM-based learning is Team Games and Tournament (TGT). TGT learning is a type of cooperative learning which involves the students' cooperation between an individual in a small group, where the students are encouraged to help each other in finishing the task given (Veloo, Md-Ali, & Chairany, 2016). The learning model of TGT involves the activities of all students without having differences in status, involves the role of students as peer tutors, and contains elements of the game (Luo, Lin, Hsu, Liao, & Kao, 2020). Salam et al., (2015) also mentioned that learning with TGT improved the students' cognitive and affective learning achievement.

During the process of TGT learning, the role of a teacher is essential. If the teacher's role as motivator and facilitator considers insufficient or the facilities available do not really support, then cooperative learning of TGT is difficult to implement (Syaifuddin, Nurlela, & Prasetya, 2020). STEM indirectly demands the teachers to think creatively and actively finding their own understanding related to the learning materials (Bozkurt & Sema, 2020; Fitrya, Adlim, Gani, Syukri, & Iqbal, 2020). Besides Conradty, Bogner, Conradty, & Bogner, (2018) explained that in TGT learning, the group score does not reflect the individual score. Therefore, the teacher should design a special assessment tool to evaluate the level of individual students' achievement. One of the assessments that can be developed is the assessment of science process skills.

Science processes skills are categorized into two; these are basic process skills and integrated process skills. In this study, we observe students' integrated science process skills. Integrated process skills are more complex skills, including the use of two or more basic skills together. Both basic and integrated scientific skills are important in any scientific investigation, such as conducting projects and carrying out experiments (Zeidan & Jayosi, 2014). Individuals with developed science process skills may have a more persistent, more meaningful, and less misconception base of knowledge because they take an active part in the process of obtaining information and they structure their own information under the supervision of their teachers (Harta et al., 2019).

Science process skill is a skill within scientific thinking and decision making. Therefore, it is important to rationalize a science curriculum in such a way as to implement science process skills (Yumusak, 2016). The science process skills give a chance for students to be able to build their own understanding through scientific experiments and analysis (Firdaus, Suratno, & Fikri, 2019). In other words, using science process skills means doing science. The purpose of science curriculums is to raise individuals who live by doing science and approach scientifically in their environment (Bekir Güler, 2019). If the students understand what science is and how it works, then they have to use their science process skills and scientific content, which are compulsory knowledge learned in the science curriculum (Duruk, Akgün, Dogan, & Gülsuyu, 2017).

Based on Zorlu & Zorlu (2017), there is a comparison between Science Process Skills with Stem Career Interests in the Middle School Students. Within the scope of improvement studies, activities and applications to develop their skills necessary for the 21st century and their science process skills should be conducted for students via STEM education. The assessment of the implications of STEM education according to (Septiani & Rustaman, 2017) plays a positive role, especially to determine the ability of students to acquire Science process skills, for their effectiveness in 21st century learning. Based on the explanation above, there is crucial to develop TGT learning model which is oriented in STEM, so trans disciplinary learning that has the potency to improve participation in science, technology, engineering, and mathematics is achieved. Moreover, TGT cooperative learning can improve the students' science process skills quality in terms of understanding, value, and attitude.

METHOD

The type of this research was research and development (RnD) (Sugiyono, 2015). This research used RnD model by Thiagarajan et al., (1976), namely the 4-D model consisting of Defining, Designing, Developing, and Disseminating. It was implemented on the material of respiratory system in the academic year of 2019/2020.

Defining stage (define): The initial stage done in this research was defining stage. There are several stages, namely front-end analysis, learner analysis, concept analysis, task analysis, and specifying instructional objectives. Designing Stage (design): The design stage aims to design learning devices. Four steps must be carried out at this stage: criterion-test construction, media selection, format selection, and initial design. Initial design is the presenting of the essential instruction through appropriate media and in a suitable sequence. Developing stage (develop); The development stage is the stage to produce a development product which is carried out in two steps, namely: expert appraisal and developmental testing. The expert appraisal is a technique for obtaining suggestions for the improvement of the material. Disseminating stage (disseminate): the terminal stages of final packaging, diffusion, and adoption are most important although most frequently overlooked (Thiagarajan et al., 1976).

Science process skill measured was a science process skill in controlling variables, interpreting data, formulating hypothesis, translating data, and experimenting.

Data Analysis Technique

The data from the result of validation were calculated by using the following Formula (1),

$$V=\frac{TSE}{TSM}x100 \quad (1)$$

Where: V = Percentage rating level; TSE = Empirical total score; and TSM = Maximum total score

The percentage data obtained by using the above formula were then transformed into qualitative descriptive data by using the following criteria can be seen further in Table 1.

Table 1. The validation criteria of learning model

No	Percentage (%)	Category
1.	85.01 – 100	Very valid
2.	70.01 – 85.00	Valid
3.	50.01 – 70.00	Less valid
4.	1.00- 50.00	Invalid

(Source: Akbar, 2013)

The analysis of product practicality was done by using the following Formula (2).

$$Pb = \frac{A}{N} \text{ x } 100\% \quad (2)$$

where Pb = The percentage of teacher's activeness; A = The total scores obtained by the teacher; and N = The Total scores.

The interpretation of *Pb* was used for the following categorizations can be seen in Table 2.

Table 2. The practicality category of learning model

Correlation number	Interpretation
$Pb > 95\%$	Very Practical
$80\% < Pb \leq 95\%$	Practical
$65\% < Pb \leq 80\%$	Sufficiently Practical
$50\% < Pb \leq 65\%$	Less Practical
$Pb \leq 50\%$	Unpractical

(Source: Sukardi, 2004)

The following Formula (3) was used to find out the improvement on the students' science process skills:

$$Pp = \frac{P}{N} \text{ x } 100 \quad (3)$$

where Pp = The students' process skills; P = The total scores of each indicator; and N = The maximum total scores.

The interpretation of *Pp* was used for the following criteria can be seen in Table 3.

Table 3. The criteria of process skill

Score	Criteria
86-100	Excellent (A)
71-85	Good (B)
56-70	Sufficiently Good (C)
≤55	Poor (D)

(Source: Widodo, Rachmadiarti, & Hidayati, 2017)

RESULTS AND DISCUSSION

Defining stage (*define*)

The initial stage done in this research was defining stage. Hasibuan, Saragih, & Amry, (2019) pointed out that this stage was intended to determine and define the learning needs by analyzing the objective and framework of the material. The results of defining stage were as follows:

According to the questionnaire distributed to twenty Senior High Schools in Jember Regency, the obtained results were 59,1% of learning method used by the teacher was the method of discussion and lecture, 20,6% of learning model implemented as *Problem Based Learning* and 20,3% used *Discovery Learning* method. The teachers were aware of the learning method of TGT, but they have never implemented it; moreover, some teachers also did not even understand and implement STEM in their learning, while few of them already did it unplanned. Regarding the assessment, the teacher used three domains covering cognitive, affective, and psychomotor to assess the students' science process skills.

The results of students' needs questionnaire distributed to 35 students showed that 70% of them understood the STEM-based learning, but it was never implemented by the teacher. And concerning the curriculum analysis, the curriculum used in this research was the 2013 curriculum which was revised in 2016.

Designing Stage (*design*)

The next stage carried out was the designing stage. Stephenson et al., (2020); Hasibuan et al., (2019) stated that the test results of the designing stage were based on the analysis of task and concept in which it was written on the objective specification of learning on defining stage (*define*). This stage played a crucial role in developing the learning model because the learning which was adjusted to the students' needs brought out meaningful and reflective learning to them. Thus, the teacher was able to adjust the learning with the students' conditions through this stage. The next one after the designing stage was the developing stage.

Developing stage (*develop*)

On this stage, the tests of validity, effectiveness and practicality are presented as follows Table 4.

Table 4. The data of validation results

No	Product	Indicator	The Average Percentage	Category
1.	Guidance Book Model	Supporting theory	75	Valid
		Learning Model Structure	87.6	Very Valid
		Learning resources	89.9	Very Valid
		Language eligibility	92.5	Very Valid
		validation mean	86.2	Very Valid
2.	Syllabus	Syllabus Identity	93.7	Very Valid
		Subject matter	87.5	Very Valid
		Assessment	75	Valid
		Time allocation	81.2	Valid
		Learning resources	87.5	Very Valid
		validation mean	84.9	Valid
3.	Lesson Plan	Learning objectives, learning methods, learning activity, Assessment, Time allocation, Learning resources	83	Very Valid
		validation mean	83	Very Valid
4.	Learning outcomes test	Content Validation	90.3	Very Valid
		Language validation	89.5	Very Valid
		validation mean	89.9	Very Valid
5.	The Instruments of Science Process Skill	Learning objectives, learning methods, alaearning activity, Assessment, Time allocation, Learning resources	88	Very Valid
		validation mean	88	Very Valid
6.	Material	Material coverage	82.5	Valid
		Material Accuracy	97.5	Very Valid
		Up-to-date Material	87.5	Very Valid
		validation mean	89.1	Very Valid
		Overall	86.8	Very Valid

Based on the average validation results, 83% was obtained on the guidance book, material, or instrument with "very valid" criteria, and the product was ready to be used for learning activity. Validation from a material expert in the form of assessments and suggestions for improvements needed so that the material aspects of the product being developed are feasible, both in the material recognition, presentation, and use of language (Sofia, Utomo, Hariyadi, Wahono, & Narulita, 2020). The validators involved two experts (lecturers) and two users (teachers) who gave comments and suggestions for better results. It was in line with the development theory of R&D, which revealed that after conduction the validation, the experts found out the weaknesses of the product being developed so that the improvement was able to be applied on it, and the product testing was then carried out (Sugiyono, 2015). Various results of educational development products require proper validation and can be justified scientifically correct before being applied (Stephenson et al., 2020).

After being validated, the next step done was conducting a trial on the small group (5-8 people) whose ability was on the average, and then it was tested out within a real class; however, if the number of students did not meet the requirement, the minimum of 20-25 students was able to represent the result of the trial (Hehakaya, Sastromiharjo, & Cahyani, 2020). The result of the trial is drawn on the following Table 5.

Table 5. The effectiveness test of science process skill to the small group

No	Meeting	Total Students	Aspect	Score		Average	Category
				Observer 1	Observer 2		
1	Meeting 1	8	Variable Controller	79.1	77.7	78.4	Good
			Data Interpretation	76.3	83.3	79.8	Good
			Hypothesis Formulation	80.5	83.3	81.9	Good
			Data Analysis	86.1	88.8	87.45	Excellent
			Experimenting	88.8	88.8	88.8	Excellent
			Average Overall meeting 1	82.16	84.38	83.2	Good
2	Meeting 2	8	Variable Controller	81.9	84.6	83.25	Good
			Data Interpretation	81.9	83.3	82.6	Good
			Hypothesis Formulation	83.3	86.1	84.7	Good
			Data Analysis	91.6	91.6	91.6	Excellent
			Experimenting	86.1	91.6	88.8	Excellent
			Average Overall meeting 2	84.9	87.4	86.2	Excellent

Based on the results, it can be concluded that the development of the learning model was proven effective on the limited test to small groups. According to the process skills score considered as good if <70% so that it can be concluded that the science process skills to small group testing were very good and the continued with the effectiveness test to the large group. The result can be seen in Table 6.

Table 6. The effectiveness test of science process skill to large group

No	Meeting	Total Students	Aspect	Score		Average	Category
				Observer 1	Observer 2		
1	Meeting 1	8	Variable Controller	83.5	83.1	83.3	Good
			Data Interpretation	84.7	87.1	85.9	Good
			Hypothesis Formulation	77.3	78.9	78.1	Good
			Data Analysis	82.8	85.1	83.95	Good
			Experimenting	89.8	91.4	90.6	Excellent
			Average Overall meeting 1	83.62	85.12	84.37	Good
2	Meeting 2	8	Variable Controller	82.4	86.3	84.35	Good
			Data Interpretation	86.3	87.8	87	Excellent
			Hypothesis Formulation	79.6	80.4	80	Good
			Data Analysis	88.2	85.1	86.6	Excellent
			Experimenting	90.6	91.4	91	Excellent
			Average Overall meeting 2	85.4	86.2	85.8	Good

The mean score of students' science process skills both at meeting I and meeting II can be categorized as good with an average of 83.9% in accordance with the category of process skills scores by the (Widodo et al., 2017). Based on the results of the scores from each aspect, the variable controller aspect obtained the lowest score, which means the 32 students faced the same difficulty. Therefore according to Martini et al., (2017), students who experienced difficulties needed to be given exercises in a variety of questions that were sufficient in number so that students' thinking activities at the application stage of the concept increased. This means that with repeated application, students were more accustomed, and their abilities improved. This can be proven by the increased ability to identify variables at the second meeting.

The aspect of formulating a hypothesis is also the aspect that has the lowest score. This is in accordance with Ratnasari et al., (2017), which states that the indicator of science process skills, which has a low percentage, is the indicator of compiling hypotheses. This low score is probably caused by the character of the respiratory system material that is considered difficult as well as too broad and make students have difficulty for understanding. Another thing as causes indicators to formulate hypotheses of low value, according to Kartimi et al., (2017) is because few students have extensive knowledge, so only a few students can answer or make temporary guesses about what the teacher asks.

Science process skills on indicators of formulating hypotheses can be trained by inviting students to formulate hypotheses before carrying out practical activities. Firdaus et al., (2018) also stated that the indicators of formulating hypotheses can be improved by accustoming students to formulating hypotheses every time they do a biology lab. In accordance with the results of interviews with teachers, students are rarely trained to formulate hypotheses during biology practicum activities so that students are confused because they are not used to it.

Strengthening the understanding given by elements of technology and engineering. These elements are presented in the form of pilot activities to make tools or objects that can simplify the work of humans (Utomo et al., 2020). This aspect was carried out with a series of practicum of designing and creating respiratory system model and prototype air filter masks by taking into account the STEM aspects outlined on the following Table 7.

Table 7. STEM aspect

Meeting 1: explaining the mechanism for air in and out in organs and respiratory tract.	
Science Aspect	The mechanism of gas exchange in the human respiratory system uses the principle of diffusion, which is the event of exchange or movement of molecules from an area with high molecular concentration to areas with low molecular concentration.
Technological Aspect	The respiratory system model in humans includes organs, channels and organ systems that work together in the human respiratory system.
Engineering Aspect	Designing and modeling the human respiratory system using secondhand materials in the surrounding environment.
Mathematical Aspect	Measuring and estimating the accuracy of the use of material that represents the respiratory tract and organs, counting how many breaths can be inhaled through the respiratory system model created.
Meeting II: explaining the effectiveness of air masks that protect the respiratory tract and organs from air pollution	
Science Aspect	The relationship between unclean environmental air, smoking behavior, and the structure of respiratory organs.
Technological Aspect	Prototype air filter mask.
Engineering Aspect	Designing and Producing prototype air filter masks.
Mathematical Aspect	Mask density, estimating the appropriate mask size so that it is comfortable to wear and can really filter the air.

Designing and creating a respiratory system model and prototype air filter masks triggered creative thinking. Aini, Narulita, & Indrawati, (2020) where students tried to create a prototype with ideas and patterns of thinking that were different from their peers. The prototype contained a key for solving the problem. These solutions were in the form of previously unrelated ideas. Those aspects enabled students to think comprehensively, so they did not stagnate at theoretical knowledge only. Students understood that the concepts they learned were useful to solve problems in real-world contexts so that the learning obtained by students was meaningful. According to Wahono, Meitanti, Utomo, & Narulita, (2018) developing learning materials based on STEM approach is useful to facilitate the students to be in touch with the world through activities such as identifying problems, gathering data to solve problems, thinking of solutions, and considering the result multidisciplinary. Moreover, learning using the STEM approach was proven to improve students' science process skills. Learning using the STEM approach is proven to improve students' science process skills. The results of this study are in accordance with research conducted by Zorlu & Zorlu (2017) that students who used STEM learning were more directed in developing scientific thinking processes using scientific stages in solving problems.

Enthusiasm was seen when the TGT took place because the students representing the team would compete individually against students from other teams. Thus, students are encouraged to solve problems, cooperate with each other, and be active and responsible for themselves and their groups. STEM learning not only for students but also affected the teacher. Eckman et al., (2016) stated that to effectively implement an integrated STEM, teachers must have an in-depth knowledge of the science, technological content, techniques, and mathematics they teach. Thus, the teacher can make the learning atmosphere livelier, increase mastery of science concepts and psychomotor skills.

Student activities can also be seen based on student worksheet analysis. Student worksheets were easier to understand the problem. This is in line with Firdaus & Narulita (2019); Jayanti, Usodo, & Subanti (2018) which stated that valid and effective teaching materials will enable students to build knowledge. Next was the practicality test following Table 8, which aimed to obtain information about the practicality of the learning model based on the predictions and considerations of the teacher after using the device during the learning process (Revita, 2019).

Table 8. Practicality test at the development stage

Result	Total students	Score %		Average	Category
		O1	O2		
Small test	8	90	80	85	Practical
Big test	8	90	90	90	Practical
Average score		90	85	87.5	Practical

The average practicality test result was 87.5; according to Karimah (2015), who said that learning model to be practical if the score obtained was 80% <Pb ≤ 95%. Professional teachers must create and foster learning activities with more new learning resources to better perceive themselves to be ready to apply ESD principles in teaching and learning activities in the fields of STEM (Manasia, Ianos, & Chicioreanu, 2020). Mauliana & Subianto (2018) also stated that students' knowledge and motivation can increase when learning to use learning tools. Sudjana (2017) also stated that the ability required in the implementation of the teaching and learning process is the activeness of teachers in creating and fostering learning activities according to the plans that have been prepared.

Active learning is a student's active impact on learning and a student's involvement in the learning process which allows students to focus on creating knowledge with an emphasis on skills such as analytical thinking (Demirci, 2017). Attracting students' attention and keeping them involved are important points for the learning process which is very important for teachers (Konopka, Adaime, & Mosele, 2015). Through the active methodology prepared by the teacher, students are able to minimize passive recipients of information (Konopka et al., 2015). There are different teaching strategies for creating an active learning environment and for engaging students in it. Recent evidence shows that active learning increases understanding and information retention (Demirci, 2017; Killian & Bastas, 2015). This is contained in the results of the implementation of learning by the observer. Based on these results, it can be concluded that this model in learning biology on respiratory system material is practical.

Disseminating stage (disseminate)

The Dissemination stage was the last stage carried out to disseminate the learning model. This can be seen in Table 9. At this stage obtained results from 2 aspects, namely effectiveness and practical aspects. Next was the result of practicality of dissemination test following Table 10.

Table 9. The effectiveness test of science process skill at dissemination stage

No	Meeting	Total Students	Aspect	Score		Average	Category
				Observer 1	Observer 2		
1	Meeting 1	8	Variable Controller	79.1	80.7	79.9	Good
			Data Interpretation	83.3	85.3	84.3	Good
			Hypothesis Formulation	82.2	79.1	80.65	Good
			Data Analysis	84.3	85.4	84.85	Good
			Experimenting	89.6	88.5	89.05	Excellent
			Average Overall meeting 1	83.7	83.8	84.37	Good
2	Meeting 2	8	Variable Controller	79.6	82.2	80.9	Good
			Data Interpretation	85.3	86.9	86.1	Excellent
			Hypothesis Formulation	80.2	82.2	81.2	Good
			Data Analysis	87.5	86.4	86.9	Excellent
			Experimenting	90.6	89.5	90	Excellent
			Average Overall meeting 2	84.6	85.4	85	Good

Table 10. The result of practicality of dissemination test

Result	Total students	Score %		Average	Category
		O1	O2		
Material I	32	100	100	100	Very Practical
Material II	32	100	90	95	Practical
Average Score		100	95	97,5	Very Practical

The results stated effective and practical. The dissemination was carried out in other classes in order to determine the effectiveness of the use of the learning model in the learning process. In addition, it was also to gather input, corrections, suggestions, assessments, as well as evaluation for making perfect the final product of development. The main recommendations of the educator during material development are to ensure flexibility in design for application across the curriculum, class time constraints, and familiarities of students with previous topics are important substances in the comprehensive dissemination of knowledge (Dora, Hanipah, & Sidek, 2012). The importance of dissemination in the development of educational products through direct trials in learning to provide reinforcement and proof of the truth of a product (Shearer, Snider, & Kniel, 2013). The existence of evaluation makes product development better (Florén, Frishammar, Parida, & Wincent, 2017; Schuh, Rebentisch, Riesener, Mattern, & Fey, 2017).

CONCLUSION

The development of the STEM-based TGT learning model was very valid with an average score of 83%, effective on science process skills with an average of 85,2.9% which included in the good category, and practical with an average of 87.5%. Thus, the STEM-based TGT learning model is ready to implement in biology teaching and learning. Therefore, it is recommended to be applied in schools.

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