

Using STEM Development Worksheets at Free Fall Motion Concept to Toward the Generic Science Skills

Didik Setiawan^{1*}, Supriyadi¹, Ellianawati¹

¹ Postgraduate Physics Education, Semarang State University, Jawa Tengah, Indonesia

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Corresponding Author:

Didik Setiawan

setiawandidik431@gmail.com

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Abstract: This study aims to analyze about the eligible, characteristics, and skill upgrade generic science for students at STEM (Science, Technology, Engineering, and Mathematics) worksheets. Evaluating student responses at STEM learning worksheets. This research is adopted by ADDIE method. It is consisting into of five stages such as analysis, design, development, implementation and evaluation. The results of study show percentage 87.80% excellent category at feasibility test. Second, the main characteristic of development student worksheet is based on STEM (Science, Technology, Engineering, and Mathematics) based learning to improve science generic skills. Third, the result of study is in science generic skills at MA Nurus Sunnah Semarang the average percentage is 80% good category with small-scale and large-scale is at Al Fattah Terboyo High School Semarang the average percentage is 85.35% excellent category at skill upgrade, it is used by students of class X MIPA SMA/MA as a supporting learning resource in the learning process. Based on text above, it can be conclude that the student are able to understand about the learning as well.

Keywords: Student worksheet; STEM; Science generic skills

Introduction

Physics is a science that teaches concepts, principles, facts, and natural laws (Maiyena et al., 2018). Physics does not only study theory, but also involves experimental activities in the laboratory. One of the physics materials carried out in the laboratory is free fall motion (Maulani et al., 2021). The method used to determine the acceleration due to gravity is the free fall motion test. Earth's gravitational acceleration can be calculated by dropping an object from a very high height. Based on the theoretical value of the acceleration due to gravity of the earth is 9.8 m/s^2 . The direction of the earth's gravitational acceleration is towards the center of the earth or straight towards the ground surface. Because the event of free fall motion is influenced by the gravitational force of the earth, the value of the acceleration of objects during free fall is close to the value of the acceleration of gravity of the earth (Idayu et al., 2019).

In the 21st century, students are expected to be able to follow the development of modern technology practically. Physics learning is transformed into mathematical equations made into practical modern technology through digital practicum tools. The availability of this digital practicum tool can increase students' interest in physics practicum and learning. Abstract and concrete concepts when students can directly observe and practice the subject matter (Maulani et al., 2021). Minister of Education and Culture Regulation Number 21 of 2016 concerning Content Standards for Primary and Secondary Education covers efforts to achieve national education goals. To achieve the national education goals, Graduate Competency Standards have been established which are criteria regarding the qualifications of graduates' abilities including attitudes, knowledge, and skills. The three competencies have different processes for receiving information. Efforts to attract graduates who show superior quality in connecting the scientific field with real life through comprehensive education (Santoso & Mosik, 2019).

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A learning approach that adopts integrated subject learning because it integrates four main areas of education, namely science, technology, mathematics, and engineering. Science related to work and energy, namely the science that studies the universe, facts, phenomena and events in everyday life. Technology and Engineering in work materials and energy are generators and power plants. Mathematics is based on the problem of free fall motion in the application of questions (Hudha et al., 2019). STEM (Science, Technology, Engineering and Mathematics) is a new approach in the development of education that combines various disciplines (Santoso & Mosik, 2019). STEM provides teachers with the opportunity to show students how science, technology, engineering and mathematics concepts, principles and techniques are used in the integrated development of products, processes, and systems used in everyday life (Agussuryani et al., 2022).

High-quality STEM education leverages many scientific inquiry and engineering design practices, supports the use of technology, integrates knowledge and skills from multiple disciplines around real-world problems, and shapes the learner's learning experience (Okulu & Unver, 2021). Learning that is associated with using STEM aspects provides opportunities for students to understand the concepts of physics combined with technology, engineering and mathematics through discussion, practicum, and project creation. The activities carried out during the learning process can attract the interest of students and have implications for improving learning outcomes. STEM is learning that involves two or more fields of science, including science, technology, engineering, and mathematics. STEM has a technological aspect that is closely related to the development of the current digital era. Technology users have the ability to access, find, and use various information available in digital technology (Asrizal & Dewi, 2018). Technological developments directly affect the economy and education itself (Yildirim & Turk, 2018). During learning, students can explore and find information about the application of technology in relation to the Physics material being studied. In the engineering aspect, students can carry out experimental work activities. Experiments are divided into two, namely real experiments and experiments in the form of virtual laboratories. In addition to conducting experiments, students can also make simple tools related to teaching materials. In addition, the mathematical aspect is used to develop mathematical equations related to the Physics material being studied. The mathematical aspect of STEM allows students to find solutions to various physics problems. All of these aspects can become reasonable knowledge when integrated in learning (Pratiwi & Ramli, 2019).

Science generic skills are intellectual skills that result from a complex combination or interaction of scientific knowledge and skills. Generic science skills can be applied to many fields. These skills can be used to learn various concepts and solve different science problems (Tawi & Liliarsari, 2014). Generic science skills are skills that must be taught and honed from an early age, especially for every high school student. Science generic skills are also classified as skills and quality of life and work. Science generic skills can be used for all types of work, including basic competencies or key skills that include cognitive, personal and interpersonal skills (Sarita & Kurniawati, 2020). According to Brotosiswoyo as quoted by Tawi & Liliarsari (2014), generic science skills in natural science learning can be classified into 9 indicators, namely: (1) direct observation; (2) indirect observation (3) awareness of scale; (4) symbolic language; (5) logical self-consistency framework of natural law; (6) logical inference; (7) the law of causality; (8) mathematical modeling; (9) building a concept (Fatimah et al., 2015).

Science generic skills-based learning has the following components: initial activities include modeling in the form of showing examples or demonstrations of the use of tools, core activities in the form of training (coaching), providing support and problem solving (scaffolding) and articulation (Fatimah et al., 2015). Generic skills are also intellectual abilities resulting from a combination or complex interaction between knowledge and skills. Generic skills include not only motor movements but also cognitive mental functions (Uliah et al., 2017).

Generic skills are important for students to learn because these skills are for career development in their field. Generic skills are not acquired suddenly, but these skills must be practiced to be further developed. Therefore, teaching and learning must be designed in such a way that students have the opportunity to hone and develop their generic skills (Hakim et al., 2018). Brotosiswoyo (2001) states that generic ability is a general ability, flexible foundation, which is not only important for the field being occupied but also in other fields (Kristianingsih et al., 2016). Generic science skills are present in every science lesson. including in this case learning Physics. Thus, generic science skills become important skills in learning and practicum related to Physics theory. Generic science skills can be practiced in physics learning on topics that are close to students' daily lives such as free fall motion.

Free fall is the motion of falling objects vertically from a certain height without initial velocity (Giancoli, 2001). Galileo argued that in free fall motion, all objects fall with the same acceleration when there is no air or other obstacles (Young, 2002). The constant acceleration of free fall is the acceleration due to the earth's gravity

(g) (Dasriyani et al., 2014). The acceleration experienced by a free fall object is called the acceleration due to gravity and is denoted by (g). Near the earth's surface, it is 9.8 m/s^2 , and points to the center of the earth. The distance traveled by the object to the ground in an interval of (t) seconds due to the acceleration due to gravity (g) can be expressed as follows:

$$h = V_0 t + \frac{1}{2} g t^2 \quad (1)$$

Where y is the length of the path, V_0 is the initial velocity as it falls, g is the acceleration due to gravity and t is the time it takes the object to reach the ground. In the concept of free fall, the value of $V_0 = 0$, so the equation becomes:

$$h = \frac{1}{2} g t^2 \quad (2)$$

$$h = \frac{2h}{t^2} \quad (3)$$

This mathematical equation is usually difficult to remember and apply, students in everyday life. This makes it difficult for students to understand physics learning, so that it has an impact on the low efficiency of student learning outcomes. In addition, physics learning that is taught in class uses an auditive method that makes students passive and less interacting with the environment. This equation is transformed into student worksheet in which there are guidelines for conducting virtual experiments using free fall motion digital practicum tools to increase students' interest in learning (Maulani et al., 2021).

Student Worksheets are usually in the form of instructions, steps for completing tasks, and tasks placed on activity sheets must clarify the basic competencies to be achieved (Depdiknas, 2008). Educators must design creative teaching materials that allow students to directly use available learning resources (Prastowo, 2012). student worksheet developed can improve problem solving, collaboration and communication competencies (Diba et al., 2017). Science generic skills-oriented student worksheet is an student worksheet designed to guide students in acquiring knowledge while improving science generic skills optimally. In science generic skills-oriented worksheets, each learning activity to acquire new knowledge takes place in a thinking process related to the generic science skills component (Virtayanti et al., 2019). In this study, the development of student worksheet containing STEM is expected to improve the generic science skills of class X students.

Based on the problems in the class that learning physics at the school has not yet developed STEM and

also regarding generic science skills as a goal in learning. In addition, the teaching materials used by students were only practical learning worksheets in Physics Curriculum 2013 which were provided from the school, where the student worksheet was considered to be less communicative so that students experienced difficulties and felt boring in understanding the contents as a result they were not read or used by students. The teaching materials used also do not present teaching materials and worksheets that can involve students' generic science skills as a whole. These conditions contributed to the fact that physics learning outcomes were still relatively low. This can be seen from the results of the physics midterm assessment for class X for the 2021/2022 school year, only 20% of students achieved the minimum completeness criterion (KKM) score set at 67.

The problems that will be examined in this study are how the feasibility of student worksheet containing STEM, how the characteristics of student worksheet containing STEM, increasing students' generic science skills after using student worksheet containing STEM, student responses after using student worksheet containing STEM in learning. This study aims to analyze the feasibility of student worksheet containing STEM, characteristics of student worksheet containing STEM, analyzing the increase in students' generic science skills after using student worksheet containing STEM.

Method

This study adapts the ADDIE development model which consists of five stages, analysis, design, development, implementation, and evaluation. This research was conducted at MA Nurus Sunnah and SMA Al Fattah Terboyo Semarang, using research subjects of class X Mathematics and Natural Sciences students. This research procedure has several stages, namely, the analysis stage, the design stage, the development stage, the implementation stage and the evaluation stage. Data collection techniques are observation, performance, questionnaires, where there is quantitative data obtained from the validation results of media experts, material experts, practitioner experts, teacher assessments, and student responses, there is also qualitative data itself described in descriptive form (Sugiyono, 2016).

Result and Discussion

This research was conducted at MA Nurus Sunnah and SMA Al Fattah Terboyo Semarang, the product was developed using the ADDIE development model which consists of five stages, namely analysis, design,

development, implementation, and evaluation. First, before the student worksheet product containing STEM is tested on students, the student worksheet is validated by an expert validator, namely a media expert validator by Dr. Nur Khoiri, M.T., M.Pd., material expert validator by Hadi Purnomo, M.Pd., practitioner expert validator by Suyanto, M.Pd. So that after the student worksheet developed is valid/feasible to use, then the school testing process is carried out to get the results.

Eligibility of STEM-loaded student worksheet

Student worksheet validation results by Media Experts

In the display aspect, the student worksheet scored 12 out of a maximum score of 16 with a percentage of 75% good criteria, the clarity aspect of the student worksheet scored 7 out of a maximum of 8 with a percentage of 87.5% very good criteria, the structural aspect of the student worksheet got a score of 31 out of a maximum score of 40 with a percentage of 77.5% good criteria, the proportionality aspect of student worksheet gets a score of 21 out of a maximum score of 24 with a percentage of 87.5% very good criteria. The average percentage obtained from the results of media expert validation is 80.68% with good criteria (decent).

Student worksheet validation results by Material Expert

In the aspect of usefulness, the student worksheet obtained a score of 14 from a maximum score of 66 with a percentage of 87.5% very good criteria, the aspect of improving the quality of students obtained a score of 22 from a maximum score of 24 with a percentage of 91.66% very good criteria, the writing aspect of the student worksheet obtained a score of 7 from a maximum score of 8 with a percentage of 87.5% very good criteria, the linguistic aspect of student worksheet obtained a score of 8 from a maximum score of 8 with a percentage of 100% very good criteria. The average percentage obtained from the results of expert practitioner validation is 91.07% with very good criteria (very feasible).

Student worksheet validation results by expert practitioners

In the material aspect, it scores 15 out of a maximum score of 16 with a percentage of 93.75% very good criteria, the learning design aspect gets a score of 20 out of a maximum score of 24 with a percentage of 83.33% very good criteria, the media and communication aspects of learning get a score of 20 out of a score a maximum of 24 with a percentage of 83.33% very good criteria, aspects of implementation power and user response obtained a score of 22 from a maximum score of 24 with a percentage of 91.66% very good criteria. The average percentage obtained from the

validation results of media experts and material experts is 87.5% with very good criteria (very feasible).

In the recapitulation of the results of the student worksheet product feasibility test containing STEM, the average percentage of student worksheet eligibility by the validator is 87.80% with very good criteria (very feasible). This is in line with research conducted by Yulianti et al. (2020), which states that the results of the STEM-based student worksheet feasibility test show the appropriate criteria for learning by obtaining an average of 88.96% which means it is very feasible. Based on the student worksheet eligibility criteria according to Arikunto (2013), the free fall student worksheet containing STEM to improve students' generic science skills is included in the very good criteria (very feasible). The same study conducted by Shabila et al, (2020), stated that the learning media in the form of STEM-based worksheets on Hooke's Law material using the ADDIE development method obtained an average validation score of 77.5% by material experts and 77.5 % by media experts. The two results of the average score by material experts and media experts are included in the "Eligible" criteria, in other words this media according to experts is feasible to use.

Feasibility Test Free Fall Motion Practicum Video

In the validation of the free fall motion practicum video to determine the effectiveness of the media carried out by media experts and material experts, it was stated that it was very good (very valid). In the questionnaire instrument validation of media experts and material experts each score for each aspect is as follows: the material aspect gets a score of 15 out of a maximum score of 16 with a percentage of 93.75% very good criteria, the learning design aspect gets a score of 20 out of a maximum score of 24 with a percentage of 83,33% very good criteria, media and learning communication aspects get a score of 20 out of a maximum score of 24 with a percentage of 83,33% very good criteria, aspects of implementation power and user response get a score of 22 out of a maximum score of 24 with a percentage of 91.66% very good criteria good. The average percentage obtained from the validation results of media experts and material experts is 87.5% with very good criteria (very feasible). Feasibility test of practicum videos conducted by media experts, material experts. Based on the results of the feasibility test that the average percentage obtained from the validation results of media experts and material experts is 87.5% with very good criteria (very feasible). After making improvements according to the validator's suggestions, the practicum video can be used for testing to students. The same study conducted by Shabila et al. (2020), stated that the learning media in the form of STEM-based worksheets on Hooke's Law material using the ADDIE development

method obtained an average validation score of 77.5% by material experts and 77.5 % by media experts. The two results of the average score by material experts and media experts are included in the "Eligible" criteria, in other words this media according to experts is feasible to use.

Characteristics of STEM-laden student worksheets

In this analysis, media experts, material experts, practitioners of the instrument were obtained to determine the characteristics of the STEM-loaded worksheets. The results of the recapitulation of the student worksheet assessment by media experts are said to be good. The indicator for the aspect of the assessment of the student worksheet display got a score of 3 with good criteria, the indicator of the aspect of the assessment of the clarity of the student worksheet got a score of 3.5 with good criteria, the indicator of the aspect of the assessment of the structure of the student worksheet got a score of 3.1 with good criteria, the indicator of the aspect of the assessment of the proportionality of the student worksheet got a value of 3, 5 with good criteria. The average percentage obtained from the result of the media expert's assessment was 3.3 with good criteria. The results of the recapitulation of the student worksheet assessment by material experts are said to be very good. In the learning design assessment aspect indicator, the score is 3.7 with very good criteria, the student worksheet readability assessment aspect indicator gets a score of 3.6 with very good criteria, the STEM study assessment aspect indicator gets a score of 3.6 with very good criteria, the achievement assessment aspect indicator student worksheet obtained a score of 3.6 with very good criteria, indicators of the conformity assessment aspect of student worksheet obtained a score of 3.3 with good criteria. The average percentage obtained from the results of the material expert's assessment is 3.6 with very good criteria. The results of the recapitulation of the student worksheet assessment by expert practitioners are said to be very good. In the indicator of the aspect of assessing the usefulness of the student worksheet, the score is 3.5 with very good criteria, the indicator of the aspect of assessment of improving the quality of students is getting a value of 3.6 with very good criteria, the indicator of the writing aspect of the student worksheet is getting a value of 3.5 with good criteria, the indicator of the assessment aspect student worksheet language score 4 with very good criteria. The average percentage obtained from the results of the expert practitioner's assessment is 3.6 with very good criteria.

Student worksheet containing STEM to improve generic science skills is divided into three parts, namely the beginning, the content, and the end. A total of 34 pages of student worksheet are made, which can be

printed using A4 paper and can be in the form of files such as E-student worksheet. This is intended so that the student worksheet developed is easy to read and in accordance with learning needs at school and outside of school. At the beginning it contains a cover, introduction, table of contents, instructions for using student worksheet, content standards, and a concept map. The front page (cover) contains the title of the student worksheet accompanied by illustrations/pictures related to the free fall motion material and the characters developed in the student worksheet, education level, name of the author, and the institution's writing (Daryanto & Dwicahyono, 2014). An introduction containing expressions submitted by the author on STEM-loaded physics worksheets to improve science generic skills and character has been made. The student worksheet brief profile contains an explanation of STEM-charged learning, science generic skills and characters contained in the student worksheet.

The table of contents contains the entire contents of the student worksheet in order, briefly, and in outline. Through this table of contents, students can easily find certain pages based on topics in the student worksheet. Instructions for using the student worksheet contain instructions on how to maximize the use of the student worksheet and some explanations regarding the contents contained in the student worksheet. The content standards in the student worksheet are arranged in tabular form with the aim of making it easier for students to find information about the knowledge, skills, and attitudes that must be mastered after students learn the free fall motion material. The concept map in the student worksheet is arranged in the form of a diagram to make it easier for students to know the meaningful relationships between concepts and emphasize the main ideas in the student worksheet. This is in line with the opinion of Widayahening (2018), which states that diagrams in the teaching and learning process are very helpful for students in understanding how a main topic can have various and interrelated ideas with one another.

In the student worksheet the content section consists of free fall motion material, practicum activity projects, examples of questions, practice questions that contain contextual elements and STEM linkages are displayed in the content of the "STEM Rubric" inserted in the material. The final part of the student worksheet developed consists of a bibliography, author's biodata. The format for compiling the contents of the student worksheet that was developed was also made consistently from the beginning to the end. This is in line with statement Arsyad (2014), that every print-based media must pay attention to the consistency of the format of its preparation. The same study conducted by Furqoniyah et al. (2022), stated that this STEM-based

student worksheet is equipped with illustrative images that can attract the attention of students. Activities in this student worksheet have project assignments that can increase the knowledge of students to apply the knowledge they have in real life. Project assignments and experiments in activities in this student worksheet use materials that are easy to find and do not burden students. The main characteristic of the student worksheet developed is STEM-based learning to improve science generic skills.

Improving students' generic science skills after using STEM-loaded worksheets

Data acquisition of generic science skills during a small-scale limited trial at MA Nurus Sunnah Semarang with a large-scale limited trial at SMA Al Fattah Terboyo Semarang was then presented in graphical form. Aspects of generic science skills shown in the graph include: indirect observation, logical framework, logical consistency, mathematical modeling. Comparison of aspects of generic science skills from MA Nurus Sunnah Semarang and SMA Al Fattah Terboyo Semarang can be seen in Figure 1.

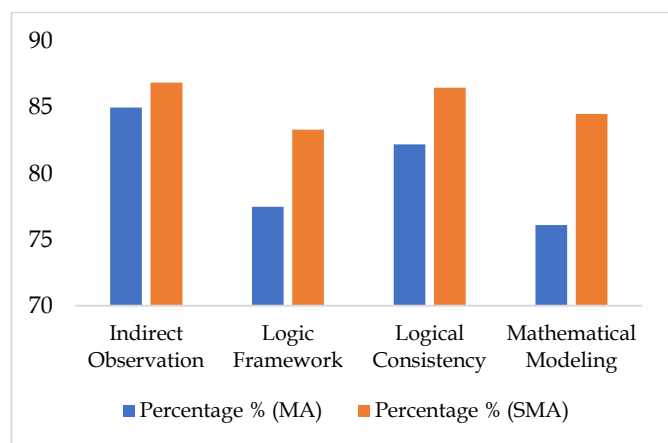


Figure 1. Science generic skills comparison chart

Based on Figure 1. that the percentage results of the generic science skills aspect of MA Nurus Sunnah Semarang and SMA Al Fattah Terboyo Semarang are as follows: indirect observation 85 % of very good criteria and 86.90 % of very good criteria, logical framework 77.5% good criteria and 83.33% very good criteria, logical consistency 82.22 % very good criteria and 86.50 % very good criteria, mathematical modeling 76.11% good criteria and 84.52% very good criteria with an average percentage of 80% good criteria and 85.35% very good criteria. Based on these results, the highest aspect of science generic skills is indirect observation. Logical consistency is in second place, logical framework is in third place and mathematical modeling is in fourth place, it can be concluded that there is an increase in science generic skills.

The generic science skill profile of the students of MA Nurus Sunnah and SMA Al Fattah Terboyo with a very good category, due to several factors including each student having different abilities in science generic skills in the use of free fall motion worksheets containing STEM. From the results of the analysis, it can be concluded that students with the KGS aspects of the logic framework and mathematical modeling still show low achievement. Every aspect of the generic science skills of students determined from SMA Nurus Sunnah and SMA Al Fattah Terboyo experienced an increase from small-scale trials to large-scale trials. This is in line with the research of Sungkawaningtyas (2018), which states that the increase in students' generic science skills results from students actively and directly participating in learning activities, such as seeking information about a problem, conducting experimental activities to prove the hypothesis, and asking the teacher. if something is not understood. Therefore, learning is no longer teacher-centered, but student-centered.

Based on the results of the above analysis regarding the development of STEM-loaded free fall worksheets to improve students' generic science skills. For class X Mathematics and Natural Sciences which has been validated by the validator, as well as observations by observers on students of SMA Nurus Sunnah and SMA Al Fattah Terboyo, it can be concluded that there is an increase and can be said to be very feasible to be applied to learning.

Conclusion

Based on the results of the research and discussion, it can be concluded that development research is carried out by adapting the ADDIE development model which consists of five stages which include analysis, design, development, implementation and evaluation. The results showed that the student worksheet feasibility test developed an average percentage of 87.80% with very good criteria. The main characteristic of the student worksheet developed is STEM-based learning to improve science generic skills. The results of the analysis of increasing science generic skills in small-scale trials at MA Nurus Sunnah Semarang the average percentage is 80% with good criteria, and large-scale trials at Al Fattah Terboyo High School Semarang the average percentage is 85.35% with very good criteria. good. Assessment of student responses to student worksheet get an average percentage of 86.78% with very good criteria, to be used by students of class X MIPA SMA/MA as a supporting learning resource in the learning process. Based on the findings, it was concluded that it had increased and was very feasible to be applied to learning.

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Author Contributions

The authors confirm contribution to the paper as follows: Study conception and design: author 1, data collection: author 1, analysis and interpretation of results: author 1,2,3, author; draft manuscript preparation: 1,2,3 authors, all authors reviewed the results and approved the final version of the manuscript. Because writers 2 and 3 act as mentors, they direct writer 1. The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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Conflicts of Interest

No Conflicts of interest.

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