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The Effect of Enviromental Pollution E-Module STEM Based (Science Technology Engineering and Mathematics) to Improve Student's Inquiry Skills

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Abstract: STEM-based learning (Sience, technology, engineering and mathematics) is a new trend in 21st century learning. The goal of this study is to determine the effectiveness of STEM-based E-Modules to enhance learners' inquiry skills on the subject of environmental pollution. The research population consisted of 340 students consisting of 190 students at SMP Negeri 3 Purwodadi and 150 students at SMP Negeri 2 Toroh. The research sample used 68 students at SMPN 3 Purwodadi and 68 students at SMPN 3 Toroh. The results of the N-Gain score test showed that the posttest value of the Limited Scale for the experimental class at SMP 3 Purwodadi ranged from 83.36% in the high category and 82.88% with the high category at SMPN 2 Toroh. Meanwhile, in the operational field scale test, the posttest scores ranged from 86.44% with the high category of SMPN 3 Purwodadi and 89.71% with the high category of SMPN 2 Toroh. The results of the Wilcoxon test at SMP N 2 Toroh and SMP 3 Purwodadi obtained a sig. 000 <0.05, then it can be implied that the hypothesis H_0 is rejected and H_1 is accepted, meaning that there is a difference in the average value of the students before being given learning using STEM-Based E-Modules and after using STEM-Based E-Modules on the subject of environmental pollution learning. The product implication is in the form of STEM-based E-Modules which are expected to increase students' inquiry skills. Suggestions for the development of a 3-dimensional Virtual Laboratory-based E-Module that integrates STEM.

Keywords: Eletronic module; Environmental pollution; Inquiry skills; Integrated science; STEM approach

Introduction

Integrated science learning is a learning that integrates Biology, Chemistry, and Physics with a learning approach that allows students to actively seek, explore, and helps students to actively look for, discover, and find ideas and principles in a complete, relevant, and active way (Kemendikbud, 2016, 2020; Kurniasih et al., 2014). 2013 curriculum learning orientation applies a scientific approach orientation to all subjects including science learning (Kemendikbud, 2016; Zubaidah et al., 2017). Science learning focuses on providing hands-on experience and meaningful learning in utilizing and applying scientific concepts, principles, and facts. In learning science, an approach is needed that facilitates students in developing students' cognitive abilities and inquiry skills. One approach that can empower students' cognitive abilities and inquiry skills is learning using the STEM approach (Billiark et al., 2014).

Inquiry skills have an important role in achieving scientific processes that facilitate students to diagnose problems, criticize experiments, plan investigations, research conjectures, seek information, build models, and formulate coherent arguments (Asnidar et al., 2018; Kristanto et al., 2015; Lusidawaty et al., 2020; Yolanda et al., 2019). The inquiry learning model is a learning model that invites students to get better understandings of science with free student activities to collect data, formulate hypotheses, form regularities (concepts), generalize a formula, prove hypotheses (Sipangkar et al., 2018). Learning with the inquiry model can improve student learning outcomes compared to conventional

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learning. Learning with inquiry learning facilitates students to carry out scientific investigations so that students can solve problems with scientific method procedures (Miftakhurrohmah et al., 2023).

Regarding the results of observations of schools in Purwodadi district, Central Java, there is a gap between expectations and reality where teachers often use conventional learning models which are believed to be unable to build the concept of student understanding and inquiry skills. This is because teacher-centered (one-way) learning makes students only listen to the teacher's explanation without any response or feedback in learning. This one-way learning activity causes student learning outcomes to be not optimal thus learners are only able to memorize concepts, principles, and theories without knowing the empirical facts. In addition, some teachers also use the Print Module as a learning support material. However, the resulting printed module has not been integrated with scientific approaches that can improve the understanding of concepts, inquiry skills, critical thinking skills, and learners' cognitive. The use of the Print Module has not been able to empower the inquiry skill ability. Because the Print Module has not presented scientific approaches such as the STEM approach. Therefore, there must be an effort to reduce the Module back in the form of digitization such as the launch of the E-Modul. E-Modules are designed to be digital-based using google sites to produce products in the form of Electronic Modules (E-Modules) that are integrated with the STEM (Science, technology, engineering and mathematics) approach.

To be able to improve learners' inquiry abilities, it is necessary to change new learning styles that must be accommodated by teachers to support fun and meaningful learning. The latest learning in the 21st century which is believed to be able to enhance the quality of science, technology, engineering, and mathematics is a STEM-based learning approach that is trained through computerized learning (Fatoni et al., 2021; Permanasari, 2016). Computerized learning is learning that utilizes teaching materials which are then converted into digital-based teaching materials, one example of digital-based teaching materials is the Electronic Module (E-Module) (Noris et al., 2021).

E-Modules are self-study resources organized into the smallest learning components that accomplish learning goals and are displayed in an electronic form with animation, audio, and navigation to make users feel more engaged with the program (Negara Sugiyanto et al., 2019). E-modules can be accessed and studied independently, free time, adequate internet and repeated regularly (Sumarmi et al., 2021). E-modules are considered to be able to empower students' inquiry and cognitive skills (Prabowo et al., 2016). The e-module is also provided with practical simulations and students can find out the completeness of learning through interactive self-evaluations. The high level of flexibility and portability of the e-module, as well as the ease of use, so that it is able to present material phenomena and the process of an event that is difficult to observe directly. An e-module can be said to be interactive if there is interaction between the user and the e-module, such as paying attention to images, text that moves and varies in color, sound, animation and even video (Hallgren et al., 2016).

E-Module learning is very essential to facilitate learning in the classroom. E-Module development must really be able to present abstract and reality problems so that students can then construct them in everyday life (Noris et al., 2023). Through the development of electronic modules, it is expected to have a positive effect on increasing the ability of learners' inquiry skills from low to high, medium to high, and those with high inquiry abilities can be maintained in learning (Sajidan et al., 2020).

Optimization of E-Modules can be done by integrating E-Modules with STEM approaches which are believed to increase students' inquiry skills. STEM is an alternative to traditional scientific education that can equip the next generation to face the obstacles of the 21st century (Sumarmi et al., 2021). The application of STEM learning can teach several cases of environmental change problems for students. Learning with four harmonious aspects to solve real problems and also for problem-based learning. This approach can generate an active learning atmosphere because these four components are required in solving problems. STEM is oriented towards problem solving activities that are faced in real terms so that students practice to find innovative solutions (Afriana et al., 2016; Pahrudin et al., 2021).

The use of STEM in learning activities that are integrated into E-Modules can have a good influence. These influences include being able to enhance learners' reasoning skills, improve students' inquiry skills, improve conceptual understanding, and learners' critical thinking skills, present data in an engaging and trustworthy manner, facilitate data evaluation, and simplify information to enhance understanding of basic concepts (Lestari et al., 2019). Teaching Science in the 21st century requires a commitment to innovation and a winner for the future through leaders in science, business, engineering and policy making. Therefore, STEM is believed to be one of the solutions that can be used to improve various abilities to encounter the issues of the 21st century (Fatoni et al., 2021).

Problems in the Purwodadi district related to environmental pollution are serious problems, therefore students are trained and empowered with a STEM-based approach with the hope that the learning implications of students can solve problems and provide alternative hypotheses related to environmental

pollution. As a result, researchers innovate to originated learning tools in the form of STEM-based E-Modules. This research was conducted to evaluate the extent of effectiveness of stem-based e-modules on cognitive abilities and inquiry skills of junior high school students in Purwodadi Regency, Central Java, Indonesia.

Method

This research was conducted at SMP Negeri 3 Purwodadi, with the address Jl. Gajah Mada No.20, North Simpang, Purwodadi, Kec. Purwodadi, Grobogan Regency, Central Java 58111. The study was run in the first semester of the 2022/2023 academic year. The research design used two groups of subjects, namely the experimental group and the control group. The experiment was treated with the use of the STEM-based Integrated Science e-Module, while the control group was given learning actions using the methods commonly used by teachers.

The Research Design is a quasi-experimental Pretest-Posttest Control Group design. The trial design can be seen in the following table:

Table 1. Research Design Pre-test Post-test Control Group

Group	Pre-test	Treatment	Post-test
Experiment Class	T1	X1	T2
Control Class	T3	X2	T4

Field trials were carried out in two classes consisting of experimental and control classes selected by purposive sampling from the entire seventh grade of SMP Negeri 3 Purwodadi. The objectives of the field trial are: (1) to test the level of implementation of the STEM-based environmental pollution e-module (2) to determine the effectiveness of the product application (STEM-Based E-Module) on the inquiry skills of junior high school students.

The research population was 340 students consisting of 190 students at SMP Negeri 3 Purwodadi and 150 students at SMP Negeri 2 Toroh. The research sample used 68 students at SMPN 3 Purwodadi and 68 students at SMPN 3 Toroh Purwodadi, Central Java, Indonesia. Related to findings of the operational field test step, the efficacy of the STEM-based e-module generated during this research was evaluated using an N-gain score which is assisted by the IBM SPSS Statistic 20 application. The formula for finding the N-score gain according to Hake (Zulaichah et al., 2021).

Table 2. Criteria for Interpretation of N-gain Scores

Range	Category
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

Result and Discussion

Learning media, both physical and technical, can help teachers communicate with learners in delivering the materials and fulfill learning goals (Tafonao, 2018). Teachers can innovate in learning such as the development of teaching materials, learning media, lesson plans and student worksheets. All of these developments lead to one goal, namely to improve students' abilities both cognitively, affectively and psychomotorically (van der Veen et al., 2017). The development of science learning media for all materials in junior high school is needed. The basic concepts of learning science and the environment in each subject are explained at this level. Teachers must be able to create media and focus learning on the nature or essence of the material (Papadouris et al., 2017). One of the initiatives that teachers must develop is to design an E-Module as a learning medium for student competency improvement programs such as inquiry skills. The design of the E-Module is intended to help students enhance their self-competence, the competence of cooperation both in the classroom and outside the classroom by utilizing the E-Module as a means of support.

Table 3. The Results of the Normality and Homogeneity Test of Students' Inquiry Skills

School	Class	Limited scale		Operational Field Scale		Kolmogorov-Smirnov Test Results	
		Normality	Information	Normality	Information	Homogeneity	Information
SMP N 3 Purwodadi	Experiment	0.366	Normal	0.079	Normal	0.176	Homogeneous
	Control	0.620	Normal	0.056	Normal		
SMP N 2 Toroh	Experiment	0.898	Normal	0.057	Normal	0.088	Homogeneous
	Control	0.143	Normal	0.098	Normal		

The results of the normality test (Kolmogorov-Smirnov) obtained sig. <0.05 in all classes so it can be implied that the data is normally distributed. While the results of the homogeneity test obtained sig. > 0.05, so it can be implied that the data is homogeneously distributed. Therefore, the distribution of data at SMP 3 Purwodadi and SMP 2 Toroh is declared to be normally

distributed and homogeneous, so that the data can be further tested with the Wilcoxon test.

E-Module is a learning media that facilitates students to facilitate learning sessions. The presence of E-Modules as a medium can help students improve student competencies such as inquiry skills where students are assisted with the concepts of mastery of science, technology, engineering, and mathematics contained in STEM learning. Learning media can help teachers create a more active learning environment that is not monotonous and not boring. This means that lecturers/teachers can create different classroom situations, determine different teaching methods, and create a healthy emotional environment among students (Adam et al., 2015). The response given by students is quite good towards the use of media in the learning process, after observing the media used by students enthusiastically conduct discussions when given practice questions so that it can be used as an indication that the media used is quite positive and even effective significantly on the student learning process (Rosanaya et al., 2021). The results of the students' N-Gain Score are shown in Table 4.

Table 4. Result of Gain Score of Students' Inquiry Skill

School	Class	Limited Scale Test			Operational Field Test		
		Pre-test	Post-test	Description	Pre-test	Post-test	Description
SMP N 3 Purwodadi	Experiment	36.87	83.63	High	35.26	86.44	High
	Control	31.25	65.00	Medium	33.91	70.82	High
SMP N 2 Toroh	Experiment	37.76	82.88	High	41.47	89.71	High
	Control	27.73	66.12	Medium	42.00	71.12	High

According to the findings of the N-Gain score test, the Limited Scale posttest scores for the experimental class at SMP 3 Purwodadi ranged from 83.36% in the high category and 82.88% with the high category at SMPN 2 Toroh. Meanwhile, in the operational field scale test, the posttest scores ranged from 86.44% with the high category of SMPN 3 Purwodadi and 89.71% with the high category of SMPN 2 Toroh. The utilization of E-Modules in learning is effective in increasing students' understanding of concepts (Herawati et al., 2018; Sumarmi et al., 2021). The use of E-Modules as digital-based learning media is highly recommended for teachers in preparing students for 21st century learning (Hendra et al., 2019). On the subject of environmental pollution education, students are expected to be able to address environmental pollution issues in social life, which can be facilitated by learning experiences in schools that are pertinent to common life. The STEM-integrated E-Module is considered to be able to empower students' inquiry skills (Bell, 2010). STEM-based learning boosts learners' inquiry. Several countries such as USA, Japan, Singapore, and Australia use STEM. STEM aims to make science, technology, engineering, and math the top job options for students. In general, the application of STEM implementation in science learning which is then integrated into E-Modules can motivate students to create, develop, and implement technology, as well as enhance cognitive, manipulative, and affective skills, and employ understanding (Permanasari, 2016).

STEM is an interdisciplinary approach that integrates science, biology, engineering, and mathematics that is matched in the context of making connections between schools and society. STEM-based learning is very important for students in science, mathematics, engineering and technology into applications and products, in addition, STEM-based learning can increase the needs of learners to think high-level, produce, ask questions, techniques and develop concepts in the fields of science, technology, engineering and mathematics (Asigigan et al., 2021). Utilizing technology in the context of education enables learners to gain access to the information they require to locate information and engage in educational activities. One of the components related to technological developments in education is learning media (Sari et al., 2021).

Table 5. The Results of the Wilcoxon Difference Test of Students' Inquiry Skills

		N	Mean Rank	Ranks Sum of Ranks
Pretest-Posttest Ability Inquiry Skill SMPN 3 Purwodadi	Negative Ranks	0[a]	.00	.00
	Positive Ranks	34[b]	17.50	595.00
	Ties	0[c]		
	Total	34		
Pretest-Posttest Ability Inquiry Skill SMPN 2 Toroh	Negative Ranks	1[d]	3.00	3.00
	Positive Ranks	33[e]	17.94	592.00
	Ties	0[f]		
	Total	34		

The results of the Wilcoxon test at SMP N 3 Purwodadi before and after being treated using the STEM-Based E-Module on the negative rank there was no posttest value lower than the pretest value. This is indicated by the acquisition of the mean rank in the range of .00, while in the positive rank that 34 students experienced an increase of 17.50 in the learning process using STEM-based E-Modules. The results of the

Wilcoxon test at SMP N 2 Toroh obtained a negative rank of 3.00, which means that there was 1 student who had the same score on the pretest and posttest, but this did not significantly affect the treatment using STEM-Based E-Module because the student scores scored high both on pretest and posttest. The positive rank is obtained in the range of 17.94% where there is a significant change from the treatment using STEM-based E-Modules.

The results of the Wilcoxon test for SMP N 2 Toroh and SMP 3 Purwodadi obtained a sig. 000 <0.05, it can be implied that the hypothesis H0 is rejected and H1 is accepted (Setyono, 2015). Regarding the findings, it can be implied that there is a difference in the average value between students before being given learning using STEM-Based E-Modules and after using STEM-Based E-Modules on the subject of environmental pollution learning. Learning by utilizing E-modules or Android-based applications can be used effectively inside or outside the school room (Arista et al., 2018).

Table 6. The Results of the Wilcoxon Different Test of Students' Inquiry Skills.

	Test Statisticsa	
	Pretest-Postest SMP N 3 Purwodadi	Pretest-Postest SMP N 2 Toroh
Z	-5.107[b]	-5.042[b]
Asymp. Sig. (2-tailed)	.000	.000

E-modules that are integrated with STEM-based learning can empower students' inquiry and cognitive abilities. The STEM-based 5E Inquiry Learning Model consists of the following phases: Engagement, exploration, explanation, elaboration, and evaluation. Underlying each phase are specific pedagogical functions that contribute to teachers' coherent instruction and learner knowledge construction. Given that STEM elements are integrated into the 5E Inquiry Learning Model, it is used STEM-based. As an illustration, the engineering component is integrated into the elaboration step as learners use technology to create and build their science and math skills (Ong et al., 2020).

E-modules are engaging, making them less difficult to utilize, and may show pictures, text, and videos, in addition to assessment and automated feedback. learning outcomes from these students (Sugihartini et al., 2017). Ease of use, attractive appearance, and communicative language used in e-modules will provide convenience for students in accessing teaching materials independently so that it will increase student motivation by displaying attractive learning media and learners' learning outcomes significantly (Pramana et al., 2020). The structural components of E-modules are generally the same as ordinary teaching materials consisting of an introduction, content and closing and are packaged in a practical and attractive manner. The digital flipbook-based e-module that was originated was assessed based on 7 component aspects, namely the material feasibility component, the language use component, the usefulness component, the design component, the layout component, the typography component and the illustration component (Yulaika et al., 2020). The use of STEM-based E-Modules is considered effective to improve students' inquiry skills. Another study explains that E-modules are effective in increasing learners' activity and learners' motivation in learning thus their learning outcomes are improved. It can be concluded that E-modules can boost learners' enthusiasm, which has an advantageous effect on learners' learning outcomes (Hastari et al., 2019).

STEM as a technology-based integrated learning approach, consists of science, technology, engineering, and mathematics that gives rise to problem solving skills. STEM is advantageous for promoting ESD because it enhances learners' ability to solve problems, increases the expertise of educators, makes teachers more pertinent (contextual), and promotes community environmental consciousness (Fakhrudin et al., 2021). The STEM approach can have learning become more creative and relevant to real-world situations. Learners are able to comprehend the surroundings and the challenges encountered by today's society, which is highly dependent on the advancement of science and technology, involving social issues (Daugherty, 2013). Using technology and real-world applications, the STEM approach may direct and teach learners to think logically, critically, evaluatively, and creatively when addressing issues and making choices related to coping with life problems (Ceylan et al., 2015). The four aspects of STEM have special characteristics that distinguish each other, but all four complement each other. The effectiveness of teaching can be improved only if the function of the system is rich and diverse so that it is close to the user's perception and attracts students to enter the learning system (Lin et al., 2017).

Teaching science and mathematics seeks to share understanding across disciplines and develop abilities and attitudes to work like scientists and mathematicians, while STEM education deals with actual-world issues and prepares students to become professionals and proficient in STEM fields and other areas (Wichaidit et al., 2019). The application of STEM-based science and physics teaching materials will be more effective if carried out at the high school level and STEM-based science and physics teaching materials have an effective influence on student learning outcomes in the realm of knowledge, skills and attitudes (Izzah et al., 2021). The nature of disciplines and the mechanisms involved in how they are connected need to be made explicit in STEM curricula and learning. STEM learning processes and practices are complex and varied (Gao et al., 2020).

Conclusion

The results of the N-Gain score test showed that the posttest value of the Limited Scale for the experimental class at SMP 3 Purwodadi ranged from 83.36% in the high category and 82.88% with the high category at SMPN 2 Toroh. Meanwhile, in the operational field scale test, the posttest scores ranged from 86.44% with the high category of SMPN 3 Purwodadi and 89.71% with the high category of SMPN 2 Toroh. The results of the Wilcoxon test at SMP N 2 Toroh and SMP 3 Purwodadi obtained a sig. 000 <0.05, then it can be implied that the hypothesis H_0 is rejected and H_1 is accepted, thus there is a contrast in the average value of the students before being given learning using STEM-Based E-Modules and after using STEM-Based E-Modules on the subject of environmental pollution learning. STEM-based E-Modules on the subject of environmental pollution have a positive impact on students, where students who study using STEM-based E-Modules have optimal learning outcomes, as well as high inquiry skill competencies. The hope is that with cognitive understanding students can implement their knowledge as a resolution in dealing with environmental pollution in the Purwodadi area in particular and in everyday life in general. The product implication is in the form of STEM-based E-Modules which are expected to increase students' inquiry skills. Suggestions for the development of a 3-dimensional Virtual Laboratory-based E-Module that integrates STEM.

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