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# Effectiveness of STEM Based Learning E-Modules (Science, Technology, Engineering, and Mathematic) Effort and Energy Materials to Improve Critical Thinking Skills in High School Students

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Keywords

Effectiveness, E-learning modules, STEM, Critical Thinking Skills

**Abstract**

Critical thinking skills are a requirement that needs to be possessed in 21st century learning. The development of e-modules based on the latest technology that can improve students' critical thinking skills is very important. The aim of this research is to determine the effectiveness of STEM-based learning e-modules on business and energy to improve critical thinking skills in high school students. Development research using 4D design. The purposive area sampling method resulted in 3 schools, namely SMAN 3 Jember, small and large group trials, distribution school trials, namely SMAN Mumbulsari and SMAN Jenggawah. The test subjects were class X high school students. The results of this research are that STEM-based learning e-modules are declared effective for improving critical thinking skills based on the N-gain value in small group trials of 0.68 in the medium category, large group trials of 0.72 in the high category, and school trials. spread of 0.65 in the medium category. The overall average N-gain value is categorized as moderate.

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## Introduction

Today's life has a big influence that comes from technological developments which have progressed over time, this is due to the connection between technology and science which

have both made progress (Maritsa et al., 2021). The current period of industrial revolution 4.0 has utilized information technology and the internet in all areas of life, including education (Risdianto, 2019). Therefore, the implementation of education, including strategies, models and learning methods, must also adapt to the needs of current developments and technology, especially the use of information technology and the internet in learning (Syamsuar & Reflianto, 2019)

Learning in the 21st century currently requires students to have several skills that need to be mastered, one of which is critical thinking skills. The school environment is a forum and place for students to learn to realize, develop and practice critical thinking skills guided by teachers to provide positive learning guidance facilities to students (Setyaningtyas, 2019). Previous research that examines critical thinking skills is research Suardi (2020) which emphasizes the importance of instilling critical thinking skills in students, because it can become a thinking hobby for anyone to learn. Therefore, this hobby should be taught in primary and secondary education. In line with research Fithri et al., (2021) critical thinking skills not only require high-level thinking abilities in exams, but also need to be trained in the learning process.

In the field of technology, almost all new technologies incorporate elements of previously developed physics research (Maknuniyah et al., 2023). Work and energy are contextual physical materials and have many applications in the surrounding environment. The material on work and energy is used as a topic to develop critical thinking skills because it has very suitable characteristics, because it has a diversity of material that is presented specifically, such as the relationship between variables, the application of the concept of the relationship between work and energy in daily activities (Majid & Linuwih, 2019). Therefore, a learning module is needed so that students can criticize how to use energy sources to be able to meet current needs and provide for future needs. According (Muttaqiin, 2023), in order to facilitate contextual physics learning, various approaches can be used by students to analyze the material concepts of work and energy in order to stimulate students' critical thinking skills. One way is to apply a STEM (Science, Technology, Engineering, and Mathematics) approach. STEM is important, this is because STEM has a way of requiring students to solve environmental problems every day along with current job needs (Widya et al., 2019).

Currently, the existence of computers and the internet has dominated almost all human activities (Ahmadi et al., 2022). According to Agustian & Salsabila (2021) in order to realize quality and increasing quality of education, adapting learning to current technological advances is needed to meet global needs, especially in learning activities. In solving these problems, there is a need for development and updates in the learning process, one of which is using interactive modules for use in learning (Rizkika et al., 2022). For students, critical thinking skills are very important to continue to improve, one of which is by developing modules based on the latest technology. One of the modules in question can be in the form of an electronic module or e-module. E-learning modules can be developed to include STEM approaches that are considered significant in developing students' critical thinking skills.

The results of the analysis of the teacher questionnaire revealed that according to 15 Physics teachers from high schools in East Java, 73.33% of teachers stated that obstacles in learning Physics were limited to the learning media available in the field. As many as 53.33% of teachers used printed learning modules during the classroom learning process, 26.67% of them used teaching materials, and 13.33% used worksheets, and as many as 6.67% used electronic modules. Meanwhile, learning that is considered suitable is one that uses a variety of methods and practicums, appropriate learning media, and is related to everyday phenomena (Nurrita, 2018). As many as 66.67% of teachers stated that they had never used certain learning methods to improve students' 21st century skills. As many as 73.33% of teachers had never trained students' critical thinking skills, and 80.00% had never applied a STEM approach during learning.

From this presentation, the researcher aims to develop a STEM-based learning e-module on business and energy material so that students critical thinking skills in learning can improve.

## Method

### Research design

The 4-D development model was chosen in the development of this e-module. The 4-D model has four stages, namely Define, Design, Develop, and Disseminate (Arum, 2020). The aim of this research is to create a STEM-based learning e-module product to improve high school students' critical thinking skills.

### Research sample

The research location using the purposive sampling area method was obtained by 3 schools, the first was SMAN 3 Jember as a small group trial and a large group trial, while the other 2 schools were used as distribution school trials, namely SMAN Mumbusari and SMAN Jenggawah. The test subjects were class X high school students for the 2023/2024 academic year.

### Research procedure

The first research procedure is definition, with several stages of analysis, namely beginning-end, students, assignments, materials, and specifications of learning objectives. The second is design, consisting of arranging the test, choosing the media, choosing the format, and initial design. The third is development, consisting of validation, revision and trial stages (small group and large group). Fourth is dissemination by distributing e-modules to several other schools (Arum, 2020).

### Data analysis

Next, tests are used as a data collection technique. Tests will be given, namely a pretest at the beginning before learning begins and a posttest at the end after the learning process using STEM-based learning e-modules. This test questions are in accordance with critical thinking indicators, namely (Interpretation, Analysis, Evaluation, Inference, Explanation, Self Regulation) (Facione, 2011). There are 6 multiple choice test questions with a score of 10 for each question. Data analysis techniques are obtained through student pretest and posttest results, then the data is analyzed using N-gain to obtain the level of student pretest and posttest results for each critical thinking indicator according to the scoring category. increase in N-gain (Kurniawan & Hidayah, 2020).

$$g = \frac{S\ post - S\ pre}{100 - S\ pre}$$

Information:
g (gain) = Increase in student test results
S pre = Average pretest (initial test)
S post = Posttest average (final test)
The gain score classification can be seen as follows:

**Table 1.** Gain Score Improvement Categories

| Intervals | Category |
|---|---|
| (g) ≥ 0,7 | Tall |
| 0,3 ≥ (g) < 0,7 | Currently |
| (g) < 3 | Low |

## Results and Discussion

### Results

After carrying out the research according to the 4D procedure stages, the students' pretest and posttest results were then analyzed using N-gain to find improvements. The following results were obtained:

**Table 2.** N-gain Results of Small Group Trials

| Critical Thinking Skills Indicator | N-Gain Score | |
|---|---|---|
| | N-Gain | Category |
| Interpretation | 0,83 | Tall |
| Analysis | 0,78 | Tall |
| Evaluation | 0,63 | Currently |
| Inference | 0,57 | Currently |
| Explanation | 0,75 | Tall |
| Self Regulation | 0,50 | Currently |
| Average | 0,68 | Currently |

The data in Table 2 above shows an increase in all indicators of critical thinking skills in small group trials. This is shown by the average N-gain score for each indicator, namely interpretation, analysis and explanation in the high category, while the evaluation, inference and self-regulation indicators are in the medium category. Thus, the average N-gain score for small group trials is moderate.

**Table 3.** N-gain Results of Large Group Trials

| Critical Thinking Skills Indicator | N-Gain Score | |
|---|---|---|
| | N-Gain | Category |
| Interpretation | 0,89 | Tall |
| Analysis | 0,86 | Tall |
| Evaluation | 0,59 | Currently |
| Inference | 0,60 | Currently |
| Explanation | 0,81 | Tall |
| Self Regulation | 0,57 | Currently |
| Average | 0,72 | Tall |

The data in Table 3 above shows an increase in all indicators of critical thinking skills in large group trials. This is shown by the average N-gain score for each indicator, namely interpretation, analysis and explanation in the high category, while the evaluation, inference and self-regulation indicators are in the medium category. Thus, the average N-gain score for small group trials is high.

**Table 4.** N-gain Results of Disseminate School Trial

| Critical Thinking Skills Indicator | SMAN Mumbulsari | | SMAN Jenggawah | |
|---|---|---|---|---|
| | N-Gain | Category | N-Gain | Category |
| Interpretation | 0,68 | Currently | 0,89 | Tall |
| Analysis | 0,74 | Tall | 0,81 | Tall |
| Evaluation | 0,48 | Currently | 0,64 | Currently |
| Inference | 0,50 | Currently | 0,66 | Currently |
| Explanation | 0,65 | Currently | 0,74 | Tall |
| Self Regulation | 0,53 | Currently | 0,52 | Currently |
| Average | 0,60 | Currently | 0,71 | Tall |

The data in Table 4 above shows an increase in all indicators of critical thinking skills in the school dissemination trial. This is shown by the average N-gain score of the analysis indicator in the high category, while the interpretation, evaluation, inference and explanation indicators are in the medium category at dissemination school 1. The average N-gain score of the interpretation, analysis, explanation and self-regulation indicators is in the category high, while the evaluation and inference indicators are in the medium category at dissemination school 2. Thus the average N-gain score for dissemination school trials is moderate.

## Discussion

Based on the data that has been presented, it is known that the interpretation indicators in the high category have descriptors, namely that students can understand the meaning of the

picture. The analysis indicators are also in the high category having descriptors. Students can write the relationships between quantities. This is because in the e-module there are example questions and also practice questions to measure students' level of success in learning activities in class (Syahiddah et al., 2021). The next indicator that is in the high category, namely explanation, has the descriptor that students can logically explain the conclusions through the writing they obtain.

Indicators that are in the medium category, namely evaluation, have the descriptor that students can write down problem solutions. The inference indicator has a descriptor, namely students are able to provide conclusions from the learning activities carried out. This is because there are still students who are less able to provide conclusions correctly and there are still some students who do not provide conclusions (Susanti et al., 2023). Furthermore, the self-regulation indicator is also in the medium category, having the descriptor that students can review after carrying out learning activities.

This STEM-based learning e-module research is as relevant as previous research where it was found that students' critical thinking skills improved due to the application of e-modules. The results of research Latifah et al (2020) also provide the same thing, namely, an increase in students' critical thinking skills with an N-gain of 0.60 is categorized as a moderate increase, so that the physics e-module created is suitable for application as an alternative physics teaching media. Furthermore, research Aulya et al (2021) based on validation results, teacher assessments, and student responses, STEM-based e-modules have the potential to be applied to high school students' learning of material. Furthermore, research conducted Umbara (2022) on the development of STEM-based e-modules obtained results that were categorized as very feasible after the pre-test and post-test results carried out in two classes showed increased learning outcomes.

## Conclusion

The development of STEM-based learning E-Modules was declared effective according to the results of the N-gain value of critical thinking skills obtained showing an average N-gain value of 0.68 in the medium category in small group trials; while the average N-gain value was 0.72 in the high category in large group trials; and the average N-gain value was 0.65 in the medium category in the school dissemination trial. The overall mean N-gain value for critical thinking skills is categorized as moderate.

### Authorship Contribution Statement

All authors contributed to the conception and design of the study. The initial to final stages which include preparing materials, collecting data, analyzing, presenting data, and final editing were carried out by Yudha. And guided by Prihatin and Putra. So that all authors have a role and contribution in completing the manuscript until the end.

## References

Agustian, N., & Salsabila, U. H. (2021). Peran Teknologi Pendidikan dalam Pembelajaran. *Islamika*, *3*(1), 123–133. https://doi.org/10.36088/islamika.v3i1.1047.

Ahmadi, M. R., Sitompul, N. C., & Hartono, H. (2022). Pengembangan Media Pembelajaran E-Modul Pekerjaan Dasar Teknik Mesin untuk Siswa SMK. *Jurnal Pendidikan Edutama*, *9*(2), 201–214. http://dx.doi.org/10.30734/jpe.v9i2.2456.

Arum, A. P. (2020). Strategi Pembelajaran Kooperatif Pada Mata Kuliah Penataan Rambut. *JTP - Jurnal Teknologi Pendidikan*, *22*(2), 132–139. https://doi.org/10.21009/jtp.v22i2.16490.

Aulya, R. A., Asyhar, R., & Yusnaidar. (2021). Pengembangan E-Modul Kimia Berbasis PjBL-STEM untuk Pembelajaran Daring Siswa SMA pada Materi Larutan Penyangga. *Journal of the Indonesian Society of Integrated Chemistry*, *13*(2), 84–91. https://doi.org/10.22437/jisic.v13i2.14506.

Facione, P. a. (2011). Critical Thinking : What It Is and Why It Counts. In *Insight assessment* (Issue ISBN 13: 978-1-891557-07-1.). https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF.

Fithri, S., Tenri Pada*, A. U., Artika, W., Nurmaliah, C., & Hasanuddin, H. (2021). Implementasi LKPD Berbasis STEM untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik. *Jurnal Pendidikan Sains Indonesia*, *9*(4), 555–564. https://doi.org/10.24815/jpsi.v9i4.20816.

Kurniawan, A. B., & Hidayah, R. (2020). Kepraktisan Permainan Zuper Abase Berbasis Android Sebagai Media Pembelajaran Asam Basa. *UNESA Journal of Chemical Education*, *9*(3), 317–323. https://doi.org/10.26740/ujced.v9n3.p317-323.

Latifah, N., Setyadi Kurniawan, E., kunci, K., Flipbook Maker, K., & Berpikir Kritis, K. (2020). Pengembangan e-Modul Fisika Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik Development of Physics E-Modules to Improve Critical Thinking Ability of Students. *Jips: Jurnal Inovasi Pendidikan Sains*, *01*, 1–7. http://jurnal.umpwr.ac.id/index.php/jips.

Majid, M. I., & Linuwih, S. (2019). Pengembangan Unit Kegiatan Belajar Mandiri (UKBM) Materi Usaha dan Energi Berbasis Pembelajaran Kontekstual untuk Meningkatkan Pemahaman Konsep Siswa. *Unnes Physics Education Journal*, *8*(3), 228–238.

Maknuniyah, L., Mahardika, I. K., & Supeno, S. (2023). *Efektivitas Model Pembelajaran DIIASE (Display Problems , Identify Problems , Investigation , Analysis , Sharing , Evaluating) untuk Meningkatkan Keterampilan Berpikir Kritis Pada Pembelajaran Fisika di SMA*. *10*(2), 33–40. http://dx.doi.org/10.30734/jpe.v10i2.3287.

Maritsa, A., Hanifah Salsabila, U., Wafiq, M., Rahma Anindya, P., & Azhar Ma'shum, M. (2021). Pengaruh Teknologi Dalam Dunia Pendidikan. *Al-Mutharahah: Jurnal Penelitian Dan Kajian Sosial Keagamaan*, *18*(2), 91–100. https://doi.org/10.46781/al-mutharahah.v18i2.303.

Muttaqiin, A. (2023). Pendekatan STEM (Science, Technology, Engineering, Mathematics) Pada Pembelajaran IPA Untuk Melatih Keterampilan Abad 21. *Jurnal Pendidikan Mipa*, *13*(1), 34–45. https://doi.org/10.37630/jpm.v13i1.819.

Nurrita, T. (2018). Pengembangan Media Pembelajaran untuk Meningkatkan Hasil Belajar Siswa. *MISYKAT: Jurnal Ilmu-Ilmu Al-Quran, Hadist, Syari'ah Dan Tarbiyah*, *3*(1), 171. https://doi.org/10.33511/misykat.v3n1.171.

Risdianto, E. (2019). Analisis Pendidikan Indonesia di Era Revolusi Industri 4.0 - Repository Universitas Muhammadiyah Sidoarjo. *Universitas Bengkulu*, *April*, 0–16. http://eprints.umsida.ac.id/6400/.

Rizkika, M., Putra, P. D. A., & Ahmad, N. (2022). Pengembangan E-LKPD Berbasis STEM pada Materi Tekanan Zat untuk Meningkatkan Kemampuan Berpikir Kritis Siswa SMP. *PSEJ (Pancasakti Science Education Journal)*, *7*(1), 41–48. https://doi.org/10.24905/psej.v7i1.142.

Setyaningtyas, E. W. (2019). Potensi Metode 1:4:P:C:R untuk Mengembangkan Keterampilan Berpikir Kritis dan Kreatif. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *9*(2), 111–121. https://doi.org/10.24246/j.js.2019.v9.i2.p111-121.

Suardi, S. (2020). Implementasi Pembelajaran Berbasis Stem Untuk Meningkatkan Kemampuan Dalam Berpikir Kritis, Kreatif Dan Bekerjasama Peserta Didik Kelas Viia Smp Negeri 4 Sibulue. *Jurnal Sains Dan Pendidikan Fisika*, *16*(2), 135. https://doi.org/10.35580/jspf.v16i2.12557.

Susanti, Pomalao, S., Resmawan, & Hulukati, E. (2023). Kemampuan Berpikir Kritis Siswa Dalam Menggunakan Multimedia Interaktif. *Differential: Journal on Mathematics Education*, *1*(1), 37–46.

Syamsuar, S., & Reflianto, R. (2019). Pendidikan Dan Tantangan Pembelajaran Berbasis Teknologi Informasi Di Era Revolusi Industri 4.0. *E-Tech : Jurnal Ilmiah Teknologi Pendidikan*, *6*(2). https://doi.org/10.24036/et.v2i2.101343.

Syarah Syahiddah, D., Dwi Aristya Putra, P., & Supriadi, B. (2021). Pengembangan E-Modul Fisika Berbasis STEM (Science, Technology, Engineering, and Mathematics) pada Materi Bunyi di SMA/MA. *Jurnal Literasi Pendidikan Fisika (JLPF)*, *2*(1), 1–8. https://doi.org/10.30872/jlpf.v2i1.438.

Umbara, D. M. A. (2022). Pengembangan E-Modul Berbasis Stem Untuk Meningkatkan Hasil Belajar Siswa Pada Materi Limbah Hasil Hewani. *Jurnal Pendidikan*, *13*(1), 32–50. https://jp.ejournal.unri.ac.id/index.php/JP/index.

Widya, Rifandi, R., & Laila Rahmi, Y. (2019). STEM education to fulfil the 21st century demand: A literature review. *Journal of Physics: Conference Series*, *1317*(1). https://doi.org/10.1088/1742-6596/1317/1/012208.