Development of a STEM-Based Integrated Chemistry E-Module to Improve Students' HOT Literacy in Colloid Systems

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Abstract. To achieve competencies that are relevant to the industrial age of the twenty-first century, the STEM approach can be used to train for the achievement of HOTS (High Order Thinking Skills). This is especially true for chemistry education. E-Modules can be used by integrating a STEM approach by considering students' HOT literacy perspective. Research and development using the ADDIE development model is the kind of study that is being conducted. The purpose of this study is to ascertain whether students' HOT literacy when using e-modules that integrate STEM approaches into colloid system material. The instruments used were material and media validity sheets filled in by two UNIMED chemistry lecturers and two chemistry teachers. Based on the results of the four validators' validation, the media validation scored 3.55 and the material validation scored 3.68, both of which were in the valid category and did not need to be revised. This study conducted a quantitative descriptive examination using experimental procedures and a one-group pretest-posttest design. The results of HOT literacy skills increase through integrated mastery with a STEM approach. This was proven through the t test, the value of $t_{count} > t_{table}$ (10.5 > 2.032245) with an N-gain value of 0.764 (76.4%). The results of the information show that the e-module created is very important and can improve students' HOT literacy skills.

Keywords: E-Module, STEM, HOT Literacy, Colloid System.

1 Introduction

[1]Learning is work that is planned, conscious, designed and can be evaluated to create and develop the capacity of students by educators [1]. [2]However, as an open system it is often

[1] Supardi, Arah pendidikan di Indonesia dalam tataran kebijakan dan implementasi. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 2(2), 2015, page 112.

[2] Adrianto, *Isu Permasalahan Pendidikan di Indonesia*, 2019, page 21.

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faced with problems, both micro and macro. Identifying this problem will provide appropriate solutions and efforts to improve it [2].

[3]The 2018 Program for Worldwide Understudies Appraisal (PISA) test results show that the educational abilities of students, especially in Indonesia, are still very low. The average score of Indonesian students, specifically 396, is still lower than the OECD's overall score of 489.. If we look at other countries, Indonesia is in 9th position on the basis of the evaluation of the science section. The average literacy score of Indonesian students shown by PISA for three consecutive years 2006-2018 was in position 393, 383, 382, 403, 396 [3].

To prepare this capacity, of course the 21st learning strategy is expected to expand students' literacy HOTS in the educational climate. This requires contributions not at the level of thought but much further, in reality. Schools as true educational institutions must be able to encourage change, especially in terms of teachers. [4]Educators must have the option to encourage change in things they can do themselves, such as preparation, implementation and assessment of learning. Higher order thinking abilities (HOTS) are a reasoning style that involves memory and deep understanding as well as basic examination [4]. [5]The capacity to associate fundamentally and imaginatively, endlessly changing information and past experiences to make choices to overcome problems in new circumstances [5]. [6]A mental movement where students utilize the highest progressive mental level, for example creating, observing, and designing [6]. [7]Stated that HOTS can rationalize and think, investigate, create, think critically and independently [7]. Bloom's Taxonomy classification consists of six components of the reasoning cycle: (1) Recall (C1 recall); (2) understand (C2 Understanding); (3) Application (C4 application); (4) Investigate (C4 inspection); (5) Assessment (C5 assessment), and (6) creation (C6 creating).

Utilizing innovation as a support for education and developing experience certainly wants to provide ideal outcomes, especially achieving learning targets. [8]Apart from that, the way the module presents material and displays the material or learning assets used by educators also influences this [8]. [9]As the front guard in training, educators should have the option to expand

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[3] OECD, Programme For International Student Assessment (PISA) Results From PISA 2018.

[4] Sambite, Mujasam, Widyaningsih, & Yusuf, Penerapan Project Based Learning berbasis Alat Peraga Sederhana untuk Meningkatkan HOT Peserta Didik. *Berkala Ilmiah Pendidikan Fisika*, *7*(2),2019, page 141.

[5] Dinni, HOT (High Order Thinking Skills) dan Kaitannya dengan Kemampuan Literasi Matematika. PRISMA, *Prosiding Seminar Nasional Matematika*, 1, 2018 page 170–176.

[6] Anderson & Krathwol, *Kerangka Landasan untuk Pembelajaran, Pengajaran dan Asesmen*: Revisi Taksonomi Pendidikan Bloom. Yogyakarta, 2015, page 142.

[7] Kurniati, Harimukti, & Jamil, Kemampuan Berpikir Tingkat Tinggi Siswa SMP di Kabupaten Jember dalam Menyelesaikan Soal Berstandar PISA. *Jurnal Penelitian Dan Evaluasi Pendidikan*, 20(2), 2016, page 142– 155.

[8] Subagia, Paradigma baru pembelajaran Kimia SMA. *In Prosiding Seminar Nasional MIPA*, 2014. page 23.

[9] Khairani, & Rajagukguk, Development of Moodle E-Learning Media in Industrial Revolution 4.0 Era. In *4th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2019). Atlantis Press*.

their skills in introducing performance materials and materials as learning capital in learning [9]. [10]It is believed that the use of innovation in the field of learning has the opportunity to further develop students' learning abilities [10].

[11]In the scientific community, e-modules are increasingly taking an important role in teaching, learning and examinations, as they help further develop access to ideal and differentiated logical material. Basically, e-modules are printed modules that are transferred into electronic structures displayed on PC media [11]. [12]The characteristics of this teaching material are the introduction of the material and other elements, for example a combination of direct access, recordings, model questions, and practice in the teaching material [12].

[13]Elective learning practices can be adjusted to meet the needs of the twenty-first century and support millennials by implementing STEM (Science, Technology, Engineering, and Mathematics) integrated learning. Integration of Science, Technology, Engineering, and Mathematics (STEM) approach module is an understanding of teaching material by combining several related literacy sciences. Learning processes in the fields of science, innovation, design and certain calculations can be realized through STEM, especially between sciences which study scientific ideas combined with current reality as applications in these fields [13].

The STEM learning process is an act of critical thinking for students by consolidating at least two interrelated literacy disciplines. The STEM approach to integrated learning comes from four perspectives, namely science, innovation, design and mathematics. Science is part of nature, the rules relating to science, physics, knowledge, as well as reality, ideas and standards. [14]The mechanical perspective is the ability to coordinate innovation, the ability to operate a device. A special point of view is information in planning and working on strategies. The Numerical Angle is the ability to direct the mind to remember the laws of information, examples, space and provide real reasons [14]. [15]As educators enter the 21st century, educators should have the option to collaborate with students with presentation materials using a STEM approach [15].

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[10] Humairah, Zainuddin, & Marham, The development of android- based interactive multimedia for high school students. In *advances in social science education and humanities research, Proceedings of the 5th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2020)* (Vol. 488, pp. 113-119).

[11] Chairul, Pahrudin, Irwandani, Triyana, dan Oktarisa, The Analysis Of Pre-Service Physics Teachers In Scientific Literacy: Focus On The Competence And Knowledge Aspects. Jurnal Pendidikan IPA Indonesia 8, no. 1, 2019, page 52–62.

[12] Muhammad Anwar, An interactive e-book development based on green chemistry study on Hydrocarbon. In *Journal of Physics: Conference Series* (Vol. 1899, No. 1, p. 012161). IOP Publishing.

[13] Irma Suwarma, Astuti Puji dan Nur Endah, Ballon Powered Car "sebagai media pembelajaran IPA berbasis STEM (Science Technology Engineering Mathematic). 8 dan 9 Juni 2015. *Prosinding Simposium Naisonal Inovasi dan Pembelajaran Sains*. Bandung.

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STEM learning can also prepare students' literacy skills. [16]Educators as complete people are expected to master the ability and capacity to adapt new innovations, have the choice to utilize media, approaches or learning models, and have the choice to develop instruments that will be used for subsequent assessments in the learning process [16]. [17]The relationship between science and technology and various other items cannot be explained in science learning. Science requires calculations as an instrument for handling information, while innovation and design which are technologies are uses of science [17]. [18]Abilities that demonstrate logical education are found in the way one engages with STEM learning. Applied learning turns out to be more meaningful in finding material ideas and investigating through action efforts to overcome problems seen from the STEM aspect and logical educational abilities [18]. [19]STEM approach integrated learning can significantly increase students' understanding through combining data, thinking, abilities, and enabling students to handle problems well [19]. [20]On the other hand, STEM can be useful in producing students who care about mechanical changes, overcome problems, find solutions, are pioneers, have sincere and intelligent brains, and become connectors between STEM integrated education and the world of work in their lives [20]. With an integrated learning approach to STEM,It is believed that students would be equipped to deal with the current phase of change, which is sometimes getting faster..

The STEM approach is regarded as essential to implement in schools since it can help pupils develop HOTS (Higher Order Thinking Skills) to achieve 21st century capabilities in the modern world.. The implementation of STEM in schools is still minimal because there is limited information for teachers regarding ways to handle STEM that are applied in developing experiences. By paying attention to the data that has been presented, a learning approach is needed which is accompanied by the selection of appropriate supporting materials to encourage HOTS literacy skills. in mastery. One of the superior learning approaches that can be created is theScience, Technology, Engineering, and Mathematics (STEM) integrated learning approach, namely an integrated learning approach that combines science, innovation, design, and calculations with the help of teaching media so that learning practices can be carried out, no matter what. drains energy, tires and makes it easier for students to retrieve and recall material so that they can revive consideration, interest in understanding, reasoning, and

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[16] Chairul, Thahir, Saregar, Choiriah, Susanti, dan Pricilia, The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding.‖ Journal of Physics: Conference Series 1467, no. 1, 2020, page 125.

[17] Afriana, Jaka, Anna Permanasari, and Any Fitriani, Penerapan Project Based Learning Terintegrasi STEM Untuk Meningkatkan Literasi Sains Siswa Ditinjau Dari Gender. 2, no. 2, 2016, 202– 12.

[18] Pratiwi, Retno Setya, and Fida Rachmadiarti, Pengembangan E-Book Berbasis Science, Technology, Engineering, and Mathematics (STEM) Materi Pertumbuhan Dan Perkembangan Tumbuhan Untuk Melatihkan Keterampilan Literasi Sains. Berkala Ilmiah Pendidikan Biologi (BioEdu) 11, no. 1, 2021, 165–78.

[19] Syahmani, Pengaruh Pembelajaran Dengan Pendekatan STEM Berbasis Lahan Basah Pada Literasi Sains Siswa. Prosiding Seminar Nasional Lingkungan. 6, no. 2, 2021, 1–5.

[20] Pratiwi, Retno Setya, and Fida Rachmadiarti, Pengembangan E-Book Berbasis Science, Technology, Engineering, and Mathematics (STEM) Materi Pertumbuhan Dan Perkembangan Tumbuhan Untuk Melatihkan Keterampilan Literasi Sains. Berkala Ilmiah Pendidikan Biologi (BioEdu) 11, no. 1, 2021, 165–78.

further increase students' literacy HOTS in learning activities to achieve the desired results in the educational process.

2 Methods

[21]This investigation is creative work, in other words it is called imaginative work (innovative work). Development research is an examination technique used to produce specific things and assess their success [21]. The ADDIE model, which has five stages—analysis, design, development, implementation, and evaluation—is used in this development research paradigm..

All of the students in class XI IPA 1 MAS Al Manar Medan Johor made up the population under investigation. The sample in the investigation was 1 experimental class using purposive sampling. This study is a quantitative descriptive study that employs experimental procedures and a one-group pretest-posttest design.. The instrument used is a test instrument. Validator in this investigation namely 2 lecturers and 2 chemistry teachers. The validation instrument used to accumulate data with validation sheets and feasibility surveys is based on BSNP criteria to check product feasibility results. Then the data from the HOT literacy test instrument was analyzed descriptively quantitatively based on the average score. Following the completion of the preparatory tests, the normality and homogeneity tests, a statistical analysis was conducted using the t test. The findings of the N-gain value showed that HOT literacy had increased.

3 Results and Discussion

In integrative development, the four STEM concepts—science, technology, engineering, and mathematics—are integrated and used in problem-based learning and real-world scenarios. [23]. STEM learning includes processes of asking, researching, and showing where students coordinate cycles and ideas in real environments ranging from science, innovation, design, and arithmetic [24]. The specialty of STEM Learning is Increasing students' capacity for configuration planning, Guiding students in dealing with problems, Increasing students' aversion to certifiable problems, Involving students in demand learning, Providing students with extraordinary opportunities to convey their points of view, Guiding students to apply STEM understanding, and connect with students in rewarding collection work.

3.1 Analyze

Conducting a requirements analysis is the first step in creating an integrated chemistry electronic module (E-module) with a STEM approach to colloid system materials. The purpose of the requirements analysis is to see how the colloid system material reflects the circumstances of the learning process. The initial analysis results are shown in the table 1.

[21] Sugiyono, *Metode Penelitian Pendidikan. Bandung*: Alfabeta, 2012, page 128.

Table 1. Average Results of Initial Analysis of Teaching Modules

Rated aspect	Average	Catergori
Material/content aspects	2.33	not worthy
Language aspect	2.46	not worthy
Presentation aspect	2.47	not worthy

The teaching materials used by teachers and students are a class XI chemistry textbook and learning resources created by the instructor in the form of PowerPoint presentations. Drawing on the examination of instructional resources, there are several shortcomings that require further development.

3.2 Design

In the design stage, the researcher combined teaching materials and literature related to colloid system material contained in the designed e-module. The instructional resources provided align with the KI and KD established in the preceding phase. The initial stage of design is collecting sources for material, grouping material such as images, videos, practical guides and student worksheets, evaluation questions and a glossary that will be included in the e-module development. The researcher designed the e-module based on the syllabus, learning plan and the results of the textbook analysis in the previous stage. The advantages of each book are taken and used in designing STEM integrated e-modules and adding the necessary parts. Apart from designing the e-module, in this phase the researcher designed a test instrument that would be used when testing validity and effectiveness testing. The E-module cover and link designed at the beginning are shown in Figure 1.

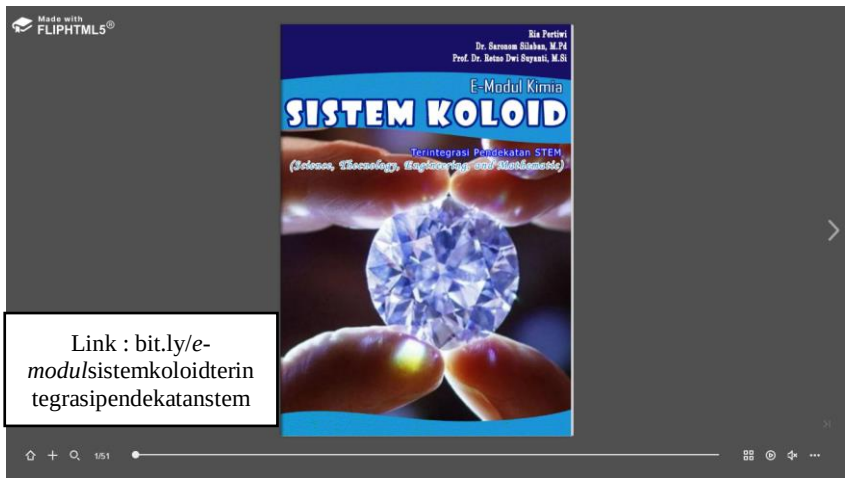

Fig. 1. Front cover of the e-module and E-module link that was created at the beginning

3.3 Development

The draft is transformed into an e-module during the development process.. Based on the draft, the researcher developed several components. Next, validation and revision were carried

out on the STEM integrated e-module that had been developed. Validation consists of 2 aspects, namely media validation and material validation. The validators consisted of four people, two lecturers at Medan State University and Two instructors of chemistry. Validators use BSNP surveys that have been modified and approved in advance. The integrated Chemistry e-module with a STEM approach created using BNSP was validated, and the findings showed that it was appropriate in terms of content (3.67), language (3.72), presentation (3.66), and graphics/media (3.55). Therefore, the resulting STEM approach integrated Chemistry e-module has very feasible eligibility requirements with an average of 3.65. The e-module validation results are in Figure 2.

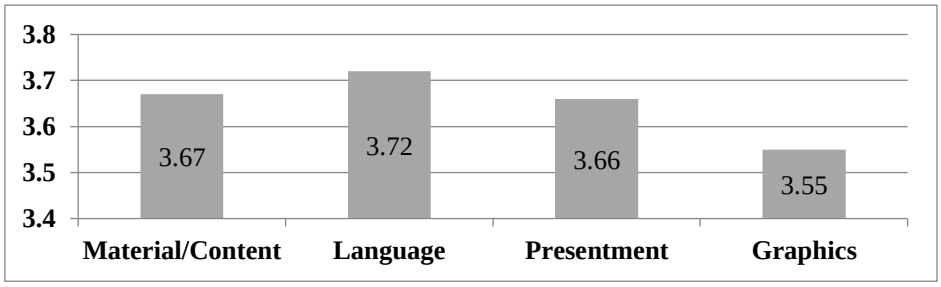

Fig. 2. Graphic of Validation Results of Integrated E-module STEM Approach

These requirements were used to construct an e-module that is suitable for usage in educational settings. However, modifications should be made using comments and input from validators to produce a better integrated STEM chemistry e-module. The following displays the e-module.

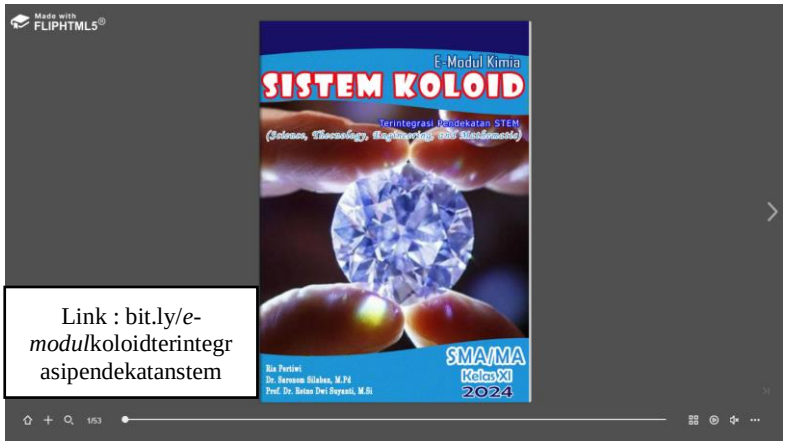

Fig. 3. Revised e-module front cover and E-module Link

A detailed explanation regarding the analysis of teaching materials according to the curriculum and according to the subject matter in the e-module.

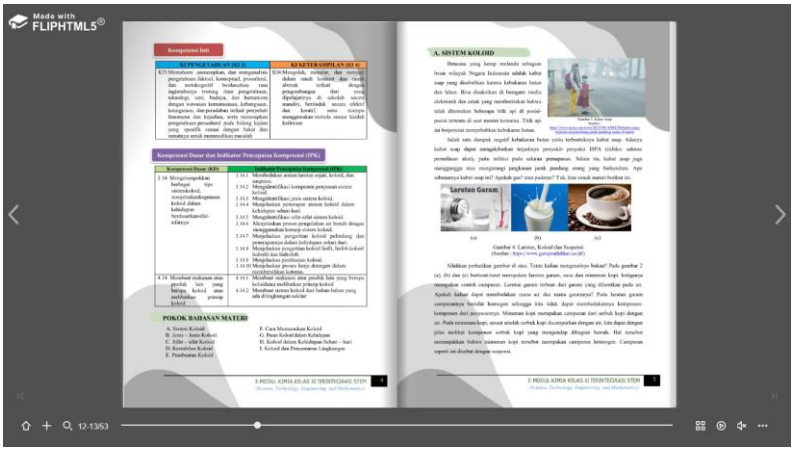

Fig. 4. KI, KD, and IPK

An explanation about STEM is attached to the introduction section so that students understand the meaning of STEM. The following is shown in Figure 5.

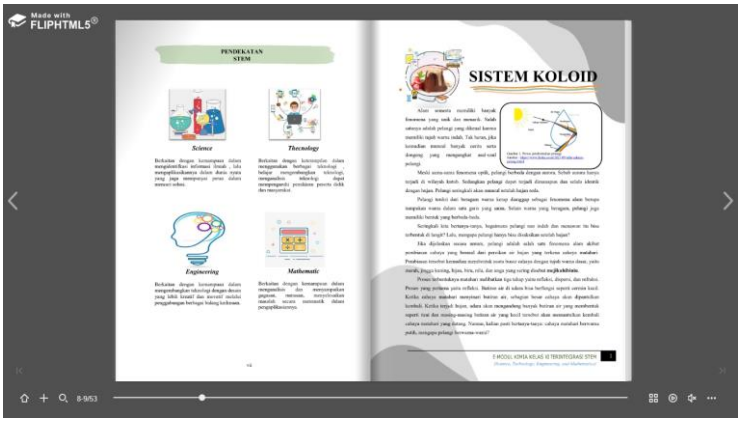

Fig. 5. STEM approach to e-modules

3.4 Implementation

In accordance to the validator's suggestions for its instructional application, the e-module has undergone a change during the implementation phase. This implementation was carried out over 4 meetings, starting from 06 to 18 May 2024 at MAS Al Manar Medan Johor. This implementation is carried out with even semester students by distributing the e-module link (bit.ly/e-modulkoloidterintegrapadutantemanstem) to students via the WhatsApp group which can then be accessed via mobile phone or laptop.

Fig. 6. Implementation of the Integrated Chemistry E-module employing a STEM approach.

The application of the integrated chemistry e-module employing a STEM approach lasted for 90 minutes with 2 weeks of meetings and was attended by 35 students. During implementation, students looked enthusiastic and enthusiastic when reading and asking questions and answers to the teacher if there were parts they did not understand. In its execution, the instructor guides the pupils to comprehend the STEM integrated chemistry e-module's content that they find confusing..

Apart from that, during learning using the integrated chemistry e-module with a STEM approach, classroom conditions were conducive. After explaining the learning material, the teacher guides students in completing the LKPD and evaluation questions in the integrated chemistry e-module employing a STEM approach. Students feel helped by learning resources using chemistry e-module integrated utilizing a STEM approach. This is because the use of e-modules in learning provides benefits such as being able to access learning materials efficiently and effectively and being easy to use flexibly anywhere and at any time.

This step was taken in order to gather information about the e-module's usefulness, the rise in HOT literacy, and the reactions of students who used the chemistry e-module, which incorporated the STEM method, during the learning process.

(a) Giving Pretest to Students

(b) Giving Posttest to Students

Fig. 7. Evaluation of the Integrated Chemistry E-module with a STEM approach

The pretest and posttest data were used to determine the increase in students' HOT literacy skills integrated with the STEM approach. The two test results are calculated to obtain the mean value, standard deviation and sample variance. After the data was tabulated, Table 2 shows the results that were achieved.

Table 2. Mean, Standard Deviation, and Variance of Pretest and Posttest data for HOT literacy skills.

Data Source	Mean	Standard Deviation	Variance
Pretest	**30.57**	**5.58**	31.10
Posttest	83.71	7.69	59.06

The Chi Square Test (X^2) was employed with a significance criterion of $\alpha = 0.05$ to ascertain if the data on pretest and posttest outcomes were regularly distributed. The calculated $X^2 < X^2$ table was used if the data met the Chi Square requirement. The table below displays the results of the pretest and posttest data normality testing.

Table 3. Normality Test Results for HOT Literacy Ability

Data	X^2_{Count}	X^2_{table}	α	Information
Pretest	**5.94**	**11.07**	**0.05**	normal distribution
Posttest	10.60	11.07	0.05	normal distribution

At a significance level of 0.05, it was determined that the pretest and posttest findings in this study were normally distributed since the normality test results table demonstrates that the pretest data meets the category X^2count < X^2 table.

In this study, students' reasoning skills were assessed using the N-Gain value following instruction in an integrated STEM approach. The HOT literacy instrument was used to administer a pretest to pupils prior to treatment. Twenty HOT literacy questions with five possible answers (options) make up the instrument, which has a 40-minute processing time. Following treatment, a posttest consisting of 20 HOT literacy items identical to the pretest was administered. The N-gain value computation revealed that students' HOT literacy had increased by 0.764, or 76.4%, as indicated in Table 4.

Table 4. N-Gain Value Interpretation Outcomes

Pretest	***Posttest***	**N**	**N-Gain**	**Interpretation N-Gain**
30.57	**83.71**	**35**	**0.764**	**High**

Using the Chi Square Test (X^2) and a significance level of α = 0.05, the normality test is performed on the N-gain data for HOT literacy ability. If the data satisfies the Chi Square criterion X^2count < X^2table, it is said to be regularly distributed. The N-Gain data normalcy test results are shown in the table below.

Table 5. N-Gain Data Normalcy Test Outcomes

Data	**X^2_{Count}**	**X^2_{table}**	**α**	**Information**
N-Gain	**9.03**	**11.07**	**0.05**	**Normal Distribution**

The requirements X^2count < X^2table (9.03 < 11.07) are known to apply to the N-gain data, according to the table of normalcy test results. Therefore, at a significance level of 0.05, it is determined that the N-gain data in this study is regularly distributed..

To ascertain the validity of the research hypothesis, a hypothesis test (t-test) was conducted in the sample group. Testing found that rejecting an invalid theory (Ho) and accepting an alternative theory (Ha), and the probability level (db) = n - 1 and α = 0.05, correspond to the dynamic measure. Here, the critical region t is more important than t(0.05)(34). This shows that thit is >1,690. Table 6 lists the outcomes of the hypothesis testing.

Table 6. Results of hypothesis testing analysis

Data Source	Data	T_{Count}	t_{table}	Information
Posttest	**$\bar{x}$ = 83,71** **S = 7,69** **μ0 = 70** N = 35	**10,55**	**1.690**	Ha accepted

Using the one sample t test equation (right side), hypothesis testing yielded a thit value of 10.55. Students' HOT literacy in colloid system content has considerably improved since the deployment of an integrated e-module using a STEM approach. To put it another way, the analysis of the hypothesis test findings indicates that tcount is outside the Ho acceptance area according to the criterion tcount > ttable, and the choice is made to accept Ho or reject Ha. The student literacy HOT value is greater than the projected value of 70.

A score of 0.764, or 76.4%, is found when the growth of HOT literacy is calculated using the N-gain value equation; this indicates that the kids' comprehension level satisfies the high N-gain criteria. This demonstrates that students' HOT competency increases by 76.39% when e-modules are used in conjunction with a STEM approach. Considering the outcomes of the speculative tests, the t_{count} value is 10.55 and the t_{table} value at t(0.05)(34) is 1.690, so it is stated that t_{count} is in the critical area with the standard $t_{count} > t_{table}$ (10.55 > 1.690) so in this review The elective value (Ha) is recognized and it is assumed that the HOT literacy value of students after using e-modules integrated with the STEM approach in colloidal material is greater than the estimated value of 70. This can happen because in learning activities, students are given the opportunity to discover characteristics of colloid systems that can be traced to general conditions.

The study's conclusions indicate that the e-module and STEM approach to studying colloid systems have met the BSNP requirements, can improve students' HOT literacy, and could be a source of information to support learning.

4 Conclusion

The following conclusions are drawn from the research's findings and the discussion that followed: (1) Following BSNP-compliant development, the e-module's practicality produced an average of 3.67 (valid) for content appropriateness, 3.72 (valid) for language suitability, 3.66 (valid) for presentation suitability, 3.55 (valid) for visual suitability, and overall It is in the high category (feasible) for use as teaching material when talking about colloid systems, with a total score of 3.65. (2) Considering the outcomes of speculative testing, the tcount value is 10.55 and the ttable value at t(0.05)(34) is 1.690, so it is stated that tcount is in the critical area with the standard $t_{count} > t_{table}$ (10.55 > 1.690) so in this review The elective value (Ha) is recognized and it is assumed that the HOT literacy value of students after using e-modules

integrated with the STEM approach in colloidal material is greater than the estimated value of 70. This can happen because in learning activities, students are given the opportunity to discover characteristics of colloid systems that can be traced to general conditions. (3) The study's conclusions indicate that the e-module and STEM approach to studying colloid systems have met the BSNP requirements, can improve students' HOT literacy, and could be a source of information to support learning..

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