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Improving Students' Concept Understanding of Lens Refraction Material by Using STEM-Based E-Modules: A Feasibility Test

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Abstract

This study aims to test the feasibility level of learning media in the form of STEM-based electronic modules on refraction material in lenses to improve the conceptual understanding of SMA / MA students. The research method used is R & D using the 4D model (Define, Design, Develop, and Disseminate). However, this research only reached the development stage by testing the feasibility of e-modules. STEM-based e-modules on lens refraction material are presented as online flipbooks so that their use can be accessed via smartphones (android or iOS). Data collection in this study was carried out by distributing feasibility test questionnaires to 3 validators consisting of 2 Physics Education expert lecturers who have taught for 1 and 2 years, 1 physics teacher who has taught for 25 years, and 53 prospective physics teachers. Based on the feasibility test results by the validator, the STEM-based e-module to improve students' conceptual understanding of lens refraction material is in the category suitable for use in learning. The implication is that because the e-module has been declared feasible in the development process, the e-module can be implemented in physics learning to increase students' conceptual understanding of the concept of refraction.

Keywords: Concept understanding; E-module; Flipbook; Refraction in the lens; STEM

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INTRODUCTION

Teaching materials are one of the important components of the learning process. According to Raharjo et al. (2018), teaching materials influence learning. They can even improve student competence if educators can be more creative in their use and not only stick to one teaching material. Teaching materials consist of modules, worksheet, enrichment books, and so on. Most of the learning media in the form of printed media displays a form that seems monotonous and directly describes the learning material, causing students to feel bored, and there is no reciprocal response during the learning process (Handayani, 2022; Herliana & Anugraheni, 2020). Therefore, it is necessary to develop learning media that can help students in the learning process so that it can run well.

Learning media needs to be well-developed, especially for subjects related to physics. Physics is one of the subjects that is considered difficult and also disliked by many students due to its various formulas and abstract concepts,

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causing students to have difficulty understanding physics concepts (Bekti et al., 2021; Jufrida et al., 2019; Karnando et al., 2023). In addition, the reason physics subjects are disliked by students can be due to the teacher's lack of ability to choose learning media that does not follow the needs of students (Syahputra et al., 2020). This shows the challenge of a physics teacher to create interesting teaching materials that can facilitate students in understanding the concept of physics material, one of which is geometric optics material.

Optics geometry is one of the subjects that is often encountered in everyday life. According to Haloho et al. (2016), geometric optics material requires students to BE able to understand how optical devices work that uses the nature of refraction light and mirroring by lenses and mirrors. Concept understanding plays an important role in building high-level knowledge. Anderson et al. (2010) stated in Bloom's taxonomy that understanding is higher than remembering; by understanding the concept well, they can explain, interpret, and compare one concept.

In general, students can only remember the material they get in learning. In this case, it can be interpreted that some students still experience misconceptions about optical material, including lens refraction. According to Suparno (2013), students think that incident light on a convex or concave lens is not refracted on the surface of the lens but in the center of the lens so that the surface of the lens and the thickness of the lens do not affect the refraction process. This is certainly not true because the light coming into the lens will be refracted and deflected on surfaces with different indices of the two mediums, namely glass and air or air and glass (Suparno, 2013). This shows that students do not understand the concept of lens refraction material.

The material refraction of light in the lens is a material that involves the physics concept of refraction of light when passing through the boundary between two mediums with different refractive indices. In this material, students will learn how lenses focus or scatter light based on this refraction process and how it can be applied in various applications of optical technology and engineering. In general, physics learning, especially lens refraction material, will run optimally if this material is presented in teaching materials using an approach that is based on the content of the material to be studied by students. One example is this lens refraction material, which is mostly related to science learning that can be applied in everyday life by utilizing technology. According to Permanasari (2016), the STEM approach is feasible for science learning because it can train students to practice applying the knowledge they have gained to make simple designs related to the environment by utilizing technology.

Pujiati (2020) stated that the STEM approach brings together science, engineering, and a combination of strategies and applications to form science learning concepts and ideas. In addition, in STEM-based teaching materials (science, technology, engineering, and mathematics), the concept of the material to be conveyed will be adjusted in everyday life (Sagala et al., 2019; Syahiddah et al., 2021). According to Suastika & Rahmawati (2019), teaching materials will be easier to understand through materials based on experiences and observations of everyday life problems. Therefore, the STEM approach is very suitable for improving students' conceptual understanding of lens refraction material because the lens refraction material is related to scientific, technological, engineering, and mathematical concepts related to everyday life. This is in line

with the research of Pangesti et al. (2017), which states that STEM-based teaching materials can increase students' mastery of concepts. This is in line with Pangesti's (2017) research, which states that STEM-based teaching materials are feasible to use and can also improve student's mastery of concepts, as indicated by the results of pretest to post-test scores.

The process of delivering material using the STEM approach will be meaningful if combined with teaching materials that meet the needs of students and the times. Entering the development of an increasingly modern era makes technological progress rapidly through scientific advances, thus affecting various fields of life, one of which is the field of education (Maritsa et al., 2021). According to Sarwendah et al. (2023), the rapid development of technology influences the world of education, where various learning models that are more innovative and varied are created. One example is the presentation of teaching materials that were originally in the form of printed media, now transformed into digital form. The presence of technology-based teaching materials makes physics learning also participate in making these developments because the physics learning process will become more effective with the help of technology and increase students' understanding (Handayani, 2022). Therefore, the development of science and technology will encourage various teaching materials that suit the needs of students.

One of the digital teaching materials that can be developed for the learning process at this time is e-modules. E-modules are teaching materials that include audio, video, animation, and navigation to become interactive teaching materials (Fauziah et al., 2022; Latif & Talib, 2021). In addition, learning media with electronic modules can assist students in understanding the material independently and can be used as notes independently (Serevina et al., 2018; Setiyani et al., 2022). In general, conventional modules have disadvantages, namely in terms of a less practical form and appearance, which seems monotonous because it can only display text and images (Hakim et al., 2020). Another case with e-modules that can present components such as text, images, videos, animations, and simulations, and in terms of its form, it is very practical so that it can be accessed anytime and anywhere (Fauziah et al., 2022; Nisa et al., 2020). The STEM-based e-module has advantages when compared to other e-modules. According to Sakdiah et al. (2020), stem-based e-modules can encourage students to design, develop, and utilize technology to understand physics material. In addition, the stem approach also presents material through elements of science, technology, engineering, and mathematics so that these four elements will drive student understanding.

Based on this description, the researcher intends to develop teaching materials in the form of STEM-based e-modules on lens refraction material to improve students' conceptual understanding. Teaching materials in the form of STEM-based e-modules are e-modules that contain material in everyday life by connecting to elements of science, technology, engineering, and mathematics. In addition, this e-module is made in the form of a flipbook or flip pdf so that students can easily access it. This study aims to determine the feasibility of STEM-based e-modules developed on lens refraction material to improve students' conceptual understanding.

METHOD

This type of research is development research (Research and Development) using the 4D approach model (Define, Design, Develop, and Disseminate) (Meishanti & Maknun, 2022). This

research aims to test the feasibility of STEM-based e-modules on lens refraction material to improve students' conceptual understanding. Therefore, this research only reached the development stage. Furthermore, the feasibility test is carried out to determine whether or not the STEM-based e-module on lens refraction material is feasible to improve students' conceptual understanding. The following are the stages of the research using the 4D approach model, which is reduced to 3D and presented in Figure 1.

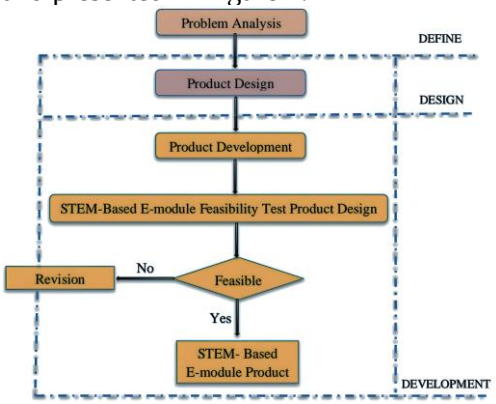

Figure 1 Flow of research and development

The define stage is carried out by analyzing the availability of teaching materials and learning media to find out the learning problems faced by students. This problem only focuses on the physics subject of lens refraction material, which is carried out through literature study activities. Furthermore, it analyzes the right solution in the form of learning media suitable for students in the 21st century, namely STEM-based e-modules. Then, determine the purpose of making STEM-based e-modules according to the problems students face. After that, conduct a literature study to analyze the indicators of STEM-based e-modules that can be used as a reference in making e-modules suitable for use as teaching materials.

The next stage is the design stage, which is carried out by determining how to develop STEM-based e-modules. The steps taken are determining student achievement indicators in lens refraction material, determining the lens refraction material used as a learning resource in the e-module, and determining the part of the lens refraction material included in science, technology, engineering, and mathematics. In this stage, the author includes videos and images in some material explanations to make it easier for students to understand the refraction material on the lens. At this stage, the author also presents practice questions in several sub-chapters of the material and adds phet simulations whose function is to make it easier for students to understand the nature of the shadows produced by convex and concave lenses. Next, design the e-module with the help of the Canva application, such as the cover display, the introduction of the e-module, and the placement of lens refraction material in the cover design. After designing the design, the author compiled the material in the predetermined e-module format. After being neatly arranged, the last step is to transform the e-module in PDF form into a flipbook using the Canva application.

After the design stage, proceed to the development stage or product development by testing the feasibility of e-modules to determine the feasibility level of the e-modules developed. This feasibility test was carried out by three testers consisting of two Physics Education expert lecturers who have taught for 1 and 2 years, one physics teacher as a practitioner who has 25 years of teaching experience, and 53 physics teacher candidate students. The feasibility test process by the three parties was carried out using an assessment questionnaire sheet. The feasibility test of this STEM-based e-module contains several aspects of assessment, including content, design, and linguistic aspects of the e-module to be developed. Based on the three aspects of the assessment, it can be formulated into 18 indicators, which

can be seen in Table 1.

Table 1 Indicators related to the assessed aspects

Aspects	Indicator
Material	1. Restate a concept of lens refraction that has been learned.
	2. Present the concept of lens refraction in various mathematical.
	3. Provide examples and non-examples of the concepts learned.
	4. Apply concepts or algorithms to problem-solving.
	5. Use, utilize, and select certain procedures.
	6. The material corresponds to the events in science.
	7. The event of lens refraction is related to technology.
	8. The lens refraction material presented is related to engineering physics.
	9. There are mathematical equations in lens refraction material.
Media	10. The overall appearance of the STEM-based e-module is attractive.
	11. Systematic presentation of e-modules.
	12. Presentation of e-modules in a flipbook.
	13. The operation of flipbook e-modules can be managed and maintained easily.
	14. Interactive presentation of supporting videos.
	15. The colors of the layout elements are harmonious and clarify functions.
	16. The font used is attractive and easy to read.
	17. Clarity of presentation of illustrations through pictures that support the material.
Linguistics	18. The sentence writing used in STEM-based e-modules is following the rules in PUEBI.

The feasibility test criteria for STEM-based e-modules on lens refraction material to improve students' conceptual understanding can be seen in Table 2 (Sugiyono, 2015).

Table 2 Likert scale criteria and scores

Criteria	Score
Very feasible	5
feasible	4
Simply	3
Less feasible	2
Very less feasible	1

Data analysis on the feasibility test can be done by grouping data in scores or values, comments, and suggestions described in the questionnaire (Salsabella et al., 2023). This study uses a questionnaire as data collection, where the measurement used is a Likert scale. The Likert scale is easy to apply, and there is freedom to enter questions in the due diligence questionnaire (Mondiana et al., 2018). Measurements using a Likert scale produce ordinal data, so the Method of Successive Interval (MSI) is needed to obtain interval data. Ningsih & Dukalang (2019) stated that the Method of Successive Interval (MSI) is a transformation method to convert ordinal data into intervals. This transformation is done because ordinal data is qualitative or only a symbol that cannot be statistically calculated (Setiaji & Dinata, 2020). After obtaining interval data, an analysis was carried out to determine the five criteria for feasibility assessment. Then, the STEM-based e-module was assessed based on five feasibility assessment criteria, which can be seen in Table 3 (Sari et al., 2022).

Table 3 Feasibility assessment criteria

Assessment Score	Criteria
$3{,}80 < X$	Very feasible
$3{,}10 < X \leq 3{,}80$	feasible
$2{,}40 < X \leq 3{,}10$	Simply
$1{,}70 < X \leq 2{,}40$	Less feasible
$X \leq 1{,}70$	Very less feasible

RESULT AND DISCUSSION

The results of developing teaching materials from this research are in the form of STEM-based electronic modules. This STEM-based e-module is presented

as a flipbook to look like a real book that can be accessed using a gadget or laptop. In this stem-based e-module, lens refraction material consists of elements of science, technology, engineering, and mathematics. In addition, this e-module is equipped with materials, images, interactive videos, and virtual labs in the form of phet simulations, sample questions, and practice questions. This study was conducted to test the feasibility of STEM (science, technology, engineering, and mathematics) based electronic module learning materials on refraction material in lenses to improve the conceptual understanding of SMA / MA students. This e-module is presented as an online flipbook through the link https://unyku.id/E-Modul-berbasis-STEM. The menu contained in this e-module is zoom, last page, previous page, enable fullscreen, and sound. This electronic module contains a cover, preface, table of contents, e-module description, STEM map, concept map, learning activities, sample questions, practice questions, and summary.

The STEM integration used in this lens refraction e-module includes science, technology, engineering, and mathematics. The science element in this lens refraction material is about scientific theories such as the theory of light refraction, Snellius law, convex lens theory, and concave lens theory. The material in this e-module follows Fathoni et al. (2020), who state that in science, students can discover scientific knowledge and the process of understanding everyday life in the surrounding environment. The following is the application of science elements in STEM-based e-modules that have been developed, as shown in Figure 2.

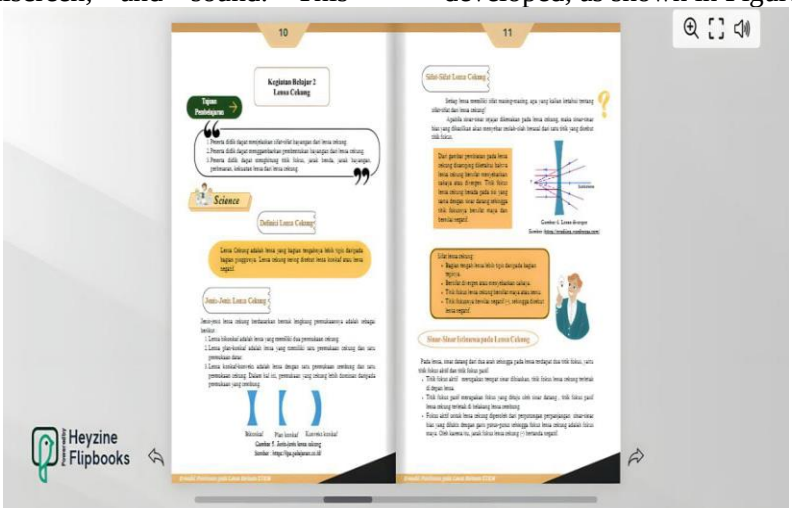

Figure 2 Elements of science in lens refraction material

The technology element in this e-module is about applying refraction material on lenses in technology that is connected to the real context. The technology part of the STEM-based e-module is found in the application of concave lens refraction to negative glasses and convex lens refraction to cameras, binoculars, microscopes, and lup. This explanation by Fathoni et al. (2020) that technology affects individuals and society. The following is the application of technological elements to the developed STEM-based e-modules, as shown in Figure 3

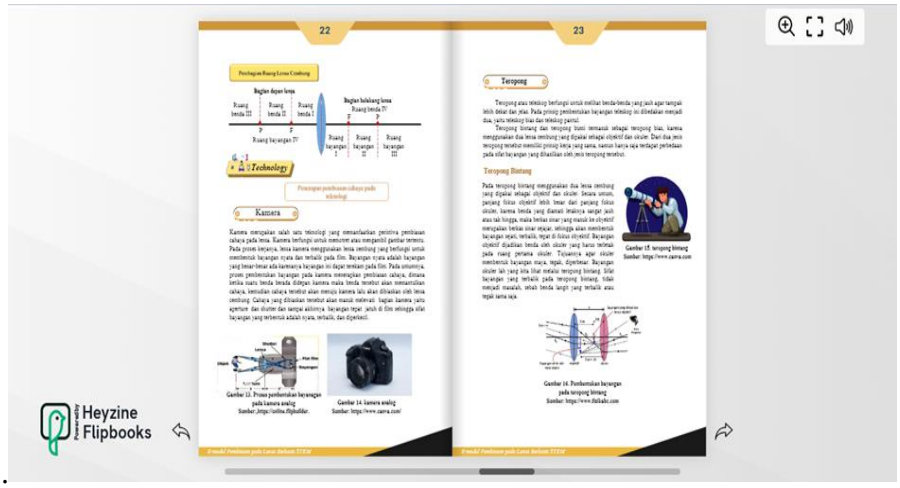

Figure 3 Technology elements in lens refraction material

Engineering in this e-module deals with "Let's Try", an explanation of the process of forming shadows on the lens, and the provision of exercises in the form of an experiment using simple tools and a phet simulation. In the experiment using simple tools, students are asked to describe the angle of incidence and angle of refraction based on the Snellius equation and then analyze the magnitude of the angle of incidence and the angle of refraction with the help of parallel planes and needles. As for using simulation phet, students are asked to describe the formation of shadows on convex lenses and concave lenses using special rays to determine the shadow properties of each lens. Then, the results of their work can be proven using simulation phet. The application of engineering elements in this e-module is by Lestari et al. (2020), who state that engineering is the knowledge to solve problems by assembling something through operating or designing a procedure. For engineering elements in STEM-based e-modules, there is material on the formation of shadows on concave and convex lenses, which are equipped with a virtual lab in the form of a phet simulation. The following is the application of engineering elements in STEM-based e-modules that have been developed, as shown in Figure 4.

Figure 4 Engineering elements on lens refraction material

Mathematics is related to the Snellius equation, which is about the angle of incidence equal to the refractive angle, the concave lens equation, and the convex lens equation consisting of the formula for the radius of curvature of the lens, the focal point of the lens, the magnification of the shadow on the lens, and the formula for the power of the lens. In addition, there are sample problems in each explanation of the equation on the material of refraction in the lens. The following is the application of

mathematics elements in STEM-based e-modules that have been developed, as shown in Figure 5.

Figure 5 Mathematics element in lens refraction

Before this STEM-based e-module is used, validators must first test it. The feasibility test of this e-module was tested by three validators consisting of 2 expert lecturers of Physics Education, one high school physics teacher, and 53 physics teacher candidate students. The following are the feasibility test results from 3 validators (testers), as shown in Figures 6, 7, and 8.

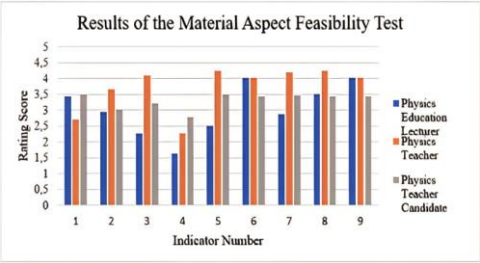

Figure 6 Graph of the results of the material aspect feasibility test

Figure 6 shows the material aspect feasibility test results by three validators. The material aspect feasibility test graph shows that almost all assessments are above 3.00 except for a few things, namely indicator four and indicator three from the Physics Education lecturer. Indicator number 3 regarding presenting the concept of lens refraction in various forms of mathematical representation. Based on comments from lecturers, this e-module does not show the characteristics of mathematical representations on conceptual understanding. Although the indicator has a low score, it can still be said to be a feasible variable. This can be seen from the average score on indicator 4, which obtained a result of 3.75. Referring to Table 3, the score between $3.10 < X \leq 3.80$ is included in the feasible category (Sari et al., 2022). Indicator number 4 is "Apply concepts or algorithms to problem-solving". The reason for the low score of this indicator is found in the validator's comment that this e-module does not show a problem that students must solve by applying the understanding of concepts obtained in the material.

The Figure 6 graph of the feasibility test results on the media aspect also shows a high assessment of above 4.00 for indicators 3, 5, 7, and 8 from the physics teacher. Indicator number 3 is " Provide examples and non-examples of the concepts learned.", and indicator number 7 is "The event of lens refraction is related to technology". These two indicators are related, namely, applying the technology element of the STEM component. The reason for the high score given by the validator is that in this e-module, the provision of examples and non-examples is presented by providing examples regarding the explanation of technological applications that use the theory of the refraction of light in the lens so that students can understand how the concept can be applied in everyday life. Indicator 5 is "Use, utilize, and select certain procedures". The reason for the high assessment of this indicator is that in the e-module, there are illustrations to exemplify the material presented in the form of practice problems to solve problems and the application of refraction material in everyday life. This

is in line with the research of Su'udiah et al. (2016), namely that providing examples accompanied by illustrations and explanations related to the surrounding environment can encourage students to manage their knowledge to make it easier for them to understand the topic. Indicator 8 is "The lens refraction material presented is related to engineering physics". The reason for the high indicator is that in this material, the engineering component is shown in the part of the shadow formation process in lens refraction, where the material explanation is accompanied by a phet simulation, which is intended to encourage student understanding and problem-solving related to the problems presented in the e-module. According to (Fauziah et al., 2022; Yusuf & Widyaningsih, 2019), e-modules with STEM integration equipped with phet simulations are the right solution so that they can train skills and improve conceptual understanding in students.

This material aspect is used to determine the suitability of the material contained in the e-module with learning objectives, the suitability of the material with indicators of conceptual understanding in students, and the suitability of the material with the approach STEM (science, technology, engineering, and mathematics). In this material aspect, there are nine assessment indicators, where the graph presents the average results of all indicators based on three validators. On the graph, the feasibility score of the material aspect of the expert lecturer is 3.02, so it is categorized as simple. The high school physics teacher validator obtained a material aspect feasibility score of 3.71, so the results of this validator were categorized as feasible. Results from student validators of prospective physics teachers: As many as 53 people obtained a material aspect feasibility score of 3.31 with a feasible category.

Based on the results of the feasibility test of material aspects from 3 validators, the average score is 3.35, so it can be concluded that the material aspects are categorized as feasible. According to Sari et al. (2022), the assessment score between $3.10 < X \leq 3.80$ is included in the feasible criteria. The results show that the lens refraction material using the STEM approach received a positive response from the validators. This positive response is because the material presented has implemented indicators of concept understanding and indicators of the STEM approach to improve students' conceptual understanding related to lens refraction material. This is in line with Hariyanto et al. (2019), who state that learning using the STEM approach can improve students' mastery of concepts. In addition, Abdi (2021) stated that applying the STEM approach in learning can improve students' understanding of concepts seen from student learning outcomes.

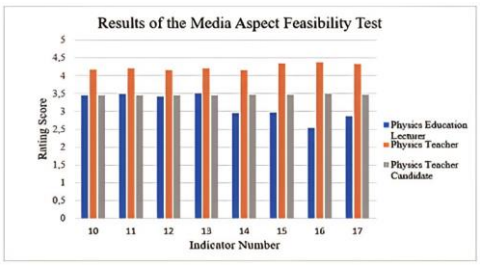

Figure 7 Graph of the results of the media aspect feasibility test

Figure 7 shows the results of the media aspect feasibility test by three validators. The media aspect feasibility test graph shows that it can be assumed that validators are interested in the media aspect. It can be seen in the media aspect feasibility test graph that the scores obtained are almost all above 3.50 except for indicators 14, 15, 16, and 17 from Physics Education lecturers. In addition, the graph above shows that the physics teacher gave an assessment score above 4.00 on all indicators. These results show that the media aspect of the e-module received a positive response from the

validator. This positive response is indicated by comments from validators, where electronic teaching materials packaged in the form of flipbooks make an interesting impression on students' learning. In addition, the flipbook can load videos, phet simulations, images, and animations, making the e-module look more fun. This is also supported by the research of Hayati et al. (2015), which states that learning media combined with text, phet simulations, animations, and videos make learning more interesting and fun.

This media aspect is used to determine the attractiveness of e-modules as a visual encouragement for students during the learning process, the systematic presentation of e-modules, and the smooth operation of flipbook-based e-modules. There are eight assessment indicators in this media aspect, and the graph presents the average results of all indicators based on three validators. On the graph, the media aspect feasibility score of the expert lecturer is 3.14, so it is categorized as feasible. The high school physics teacher validator obtained a media aspect feasibility score of 4.24, so this validator's results were categorized as very feasible. Results from student validators of prospective physics teachers, as many as 53 people obtained a media aspect feasibility score of 3.46 to categorize it as feasible.

Based on the results of the media aspect feasibility test from 3 validators, the average score is 3.61, so it can be concluded that the material aspect is categorized as feasible. Referring to Table 3, the assessment score in the $3.10 < X \leq 3.80$ range is included in the feasible category (Sari et al., 2022). The results show that the e-module developed can provide convenience for students in learning, the design used is attractive, and the illustrations presented can be read clearly so that it can make students interested in learning. According to (Irkhamni et al., 2021: 133), the attractiveness of a systematically arranged learning design is one of the most important parts of the learning process. In addition, attractive learning media is also needed by students to understand the material well and provide a good stimulus (Maulina & Pahamzah, 2019; Sutarno & Mukhidin, 2013).

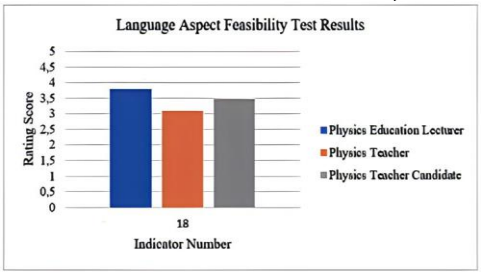

Figure 8 Graph of the language aspect feasibility test results

Figure 8 shows the feasibility test of linguistic aspects by three validators. The linguistic aspect determines the suitability of sentence writing used in STEM-based e-modules with the rules in PUEBI. In this linguistic aspect, there is one assessment indicator, where the graph presents the average results of all indicators based on three validators. On the graph, the feasibility score of the linguistic aspect of the Physics Education lecturer is 3.79, so it is categorized as feasible. The high school physics teacher validator obtained a feasibility score for the language aspect of 3.08, so this validator's results were categorized as simple. The results of the student validators of prospective physics teachers showed that as many as 53 people obtained a feasibility score for the language aspect of 3.46, so it was categorized as feasible.

Based on these results, it can be concluded that the feasibility test results on the linguistic aspect obtained an average score of from 3 validators 3.44. Sari et al. (2022) stated that an assessment score between $3.10 < X \leq 3.80$ can be categorized as feasible. This result indicates that the writing or

language presented in the learning media has followed the rules contained in PUEBI. This is reinforced by the validator's comments stating that the material is presented using effective sentences that make it easier for students to understand the concepts in the lens refraction material. According to Pratama et al. (2018), the language used to convey material through learning media is simple, easy to understand, and efficient. Prastowo (2015) also emphasizes that the writing style used to convey the material through the learning media developed should be adjusted to the material and students' abilities. Based on this, students will more easily remember and understand the material they are learning, so that students' ability to understand the concept of refraction can increase.

Based on the feasibility test results from the three aspects of the assessment, the overall average score is 3.47. These results are stated in the feasible category. Sari et al. (2022) state that the assessment score between $3.10 < X \leq 3.80$ can be declared feasible. This study's results align with Syahiddah et al. (2021), who state that STEM-based teaching materials are feasible to use to improve students' conceptual understanding of learning.

The advantages of teaching materials on lens refraction material in STEM-based e-modules include supporting videos related to the material presented. This supporting video aims to facilitate students' understanding of the concepts that have been obtained from the material. The material in the e-module is presented simply and concisely so that it is effective for students to learn. This teaching material also presents illustrative images that illustrate a theory. Illustrative images provide an overview of a process, phenomenon, or event so that students have an image related to lens refraction material.

This e-module also has a supporting application in the form of a virtual lab or phet. The existence of phet is intended so that students can prove the theory in the material and supporting videos so that student's understanding of concepts will be stronger and increase. This is by (Fauziah et al., 2022; Yusuf & Widyaningsih, 2019) that e-modules with STEM integration equipped with virtual lab applications in the form of phet simulation are the right solution so that they can train skills and improve conceptual understanding in students. In this case, it is reinforced by suggestions or arguments from respondents that STEM-based e-module teaching materials are displayed in an attractive and varied manner so that students do not feel bored using this e-module. Students also gain new experiences with supporting videos and supporting applications in the form of Phet simulation.

Based on suggestions from validators, it can be obtained that the teaching materials developed can be implemented. However, the material presented should add a problem that students must solve by applying the understanding of concepts obtained in the material. In addition, each learning activity begins with an exploration activity that stimulates learning and a student's attraction to the topic to be studied, followed by a Student Activity Sheet. This will eliminate the impression that the module is not just a collection/summary of material on a topic.

CONCLUSION

Based on the analysis and discussion results, it can be concluded that the STEM-based e-module is feasible to use in the learning process at the high school level. The e-modules that have been developed are declared feasible by examiners from experts and practitioners, with an overall score of 3.47 in the feasible category. The implication is that

this e-module can be implemented in physics learning to increase students' conceptual understanding of refraction material.

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