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An Ethnophysics E-Module Based on Indonesian Bamboo Spinning Tops for Contextual Mechanics Learning

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Abstract: This study aimed to analyze the characteristics of an integrated ethnophysics e-module for mechanics learning, determine its validity based on expert evaluations, and examine students' responses toward its implementation. The study employed a Research and Development (R&D) method using the Four-D development model consisting of define, design, develop, and disseminate stages. The main characteristics of the developed e-module included integration of PDF and Google Sites, ethnophysics context and Magnus effect approach, multirepresentation mechanics materials, interactive multimedia features. The validation results showed that the developed e-module achieved an average percentage of 89.58% from material experts and 85.00% from media experts, both categorized as highly valid. In addition, the student response results obtained an average percentage of 90.25%, categorized as very positive. These findings indicate that the developed ethnophysics e-module has the potential to support contextual, interactive, and technology-based mechanics learning through the integration of local cultural phenomena and digital learning media.

Keywords: Ethnophysics; Mechanics learning; E-Module; Bamboo spinning top; Google sites

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Introduction

Mechanics in higher education plays an important role in developing students' understanding of fundamental physics concepts such as force, torque, and angular momentum (Munfaridah *et al.*, 2021; Sarapak *et al.*, 2025). The mathematical and abstract nature of mechanics concepts requires strong visualization skills and conceptual understanding. The development of digital technology provides opportunities for the creation of interactive learning media that can support the visualization of mechanics concepts in a more dynamic manner (Ullayla & Malik, 2024; Yang, 2025). In addition, the integration of local cultural contexts through an ethnophysics approach may help students understand the relationship between scientific concepts and cultural phenomena that are closely related to their daily lives, making learning more contextual and relevant (Dewi *et al.*, 2019; Simamora *et al.*, 2019). In the learning process, students are not only expected to understand mathematical formulations, but also to relate them to physical phenomena encountered in everyday life (Samadun & Dwikoranto, 2022). Therefore, learning media that provides more contextual and meaningful learning experiences are needed to help students understand mechanics concepts more applicative.

The development of digital technology has encouraged transformations in educational media, including physics learning (Kaushik *et al.*, 2023; Vysochan *et al.*, 2024). One of the most widely developed media is the e-module, as it provides flexible, independent, and easily accessible learning opportunities. E-modules allow the integration of multimedia elements such as images, videos, simulations, and animations, which can increase student engagement during the learning process (Maisaroh & Sulisworo, 2025; Zhitfi & Iriaji, 2025; Afianti *et al.*, 2026). The use of interactive digital learning media may also help students visualize abstract physics concepts through more dynamic and contextual representations (Widiningrum *et al.*, 2024). In addition, multimedia integration in e-modules supports the creation of more engaging and student-centered learning experiences. Nevertheless, most existing e-modules remain relatively static and have not optimally integrated structured learning materials with interactive digital learning environments.

Therefore, there is a need to develop digital learning media that are not only informative but also capable of connecting conceptual materials with more interactive and contextual learning experiences.

One approach that can be used to create contextual physics learning is ethnophysics. Ethnophysics refers to a learning approach that connects physics concepts with culture, local wisdom, and traditional community practices (Ariani & Hariyadi, 2024). The integration of local culture into physics learning not only helps students understand concepts in ways that are closer to their daily lives, but also contributes to the preservation of local culture amid the rapid development of modern education. In the context of physics education, ethnophysics is considered capable of creating more meaningful learning experiences because students can learn scientific concepts through cultural phenomena that are familiar to them (Batlolona *et al.*, 2022; Alibar *et al.*, 2024).

One form of Indonesian local wisdom that has strong potential for mechanics learning is the traditional bamboo spinning top commonly found in Yogyakarta and Central Java. Bamboo spinning tops contain various mechanics concepts, including moment of inertia, torque, precession, nutation, drag force, and the Magnus effect. When the spinning top rotates and moves across a surface, complex physical phenomena emerge, making it suitable as a contextual representation of mechanics learning (Cross, 2013). Besides its scientific value, the bamboo spinning top also represents an important element of Indonesian cultural heritage. However, studies discussing bamboo spinning tops within ethnophysics contexts and digital learning media development remain limited, particularly in higher education mechanics learning.

Previous studies have generally discussed spinning top motion from theoretical and experimental mechanics perspectives. Vibrik (2012) focused on the theoretical modeling of spinning top rotational dynamics using quaternion algebra, whereas Cross (2013) examined spinning top trajectories and precession through experimental observations. However, ethnophysics-based learning media development remains relatively rare. In addition, the development of e-modules integrating structured PDF materials with interactive learning platforms such as Google Sites is still limited. In fact, the integration of these two platforms has the potential to create more flexible, structured, and interactive digital learning environments (Bueno *et al.*, 2022; Amaniampong & Hartmann, 2023). Therefore, there is a need for learning media that integrate mechanics concepts, ethnophysics approaches, and digital technology within a connected learning environment.

Based on these considerations, this study aims to develop an integrated ethnophysics e-module based on Indonesian bamboo spinning tops for mechanics learning. The e-module was developed by integrating PDF-based materials with Google Sites to provide more flexible, interactive, and contextual learning experiences. In addition, this study aims to analyze the characteristics of the developed e-module, its validity based on expert evaluations, and students' responses toward its implementation in mechanics learning.

Methods

This study was conducted in the Physics Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang from February to March 2026. The participants consisted of expert validators and university students. The validators included material experts and media experts with expertise in physics and educational media development. Meanwhile, student responses were collected from students who had completed mechanics courses in order to obtain feedback regarding the developed e-module.

This study employed a *Research and Development* (R&D) method using the Four-D development model consisting of the *define*, *design*, *develop*, and *disseminate* stages. This model was selected because it provides a systematic procedure for developing valid learning media aligned with educational needs. In this study, all development stages were conducted up to a limited *disseminate* stage through the implementation of the e-module and the collection of student responses toward the developed media. The development process used in this study followed the Four-D model as illustrated in Figure 1.

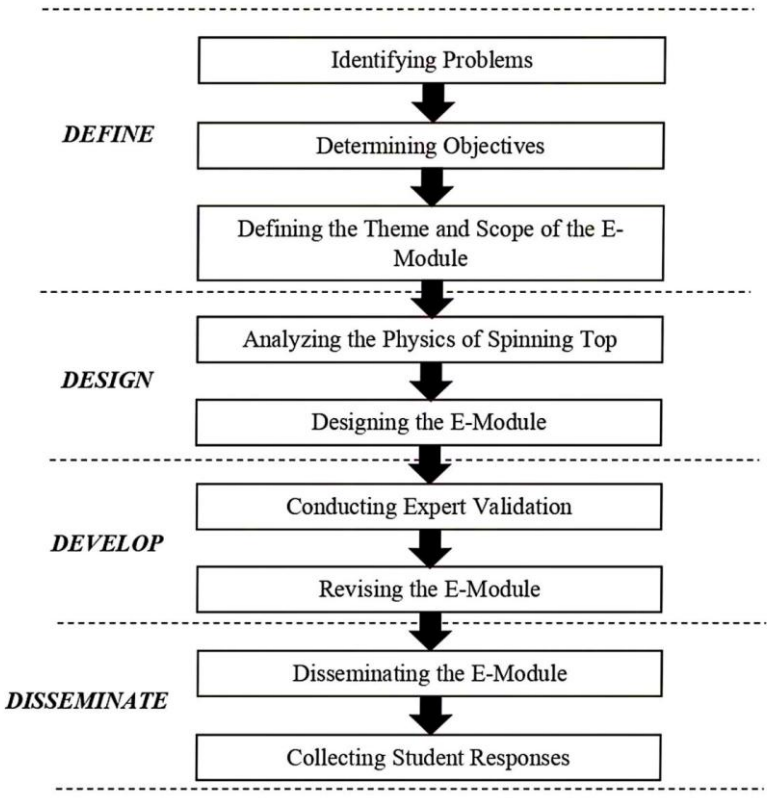


Figure 1. Four-D Development Procedure

During the define stage, several preliminary activities were conducted, including identifying problems in mechanics learning, determining the objectives of the developed learning media, and defining the theme and scope of the e-module. This stage was carried out through literature review and observations of mechanics learning in higher education to identify students' needs for contextual digital learning media. In addition, the potential of Indonesian bamboo spinning tops as an ethnophysics context for mechanics learning was examined.

The design stage involved analyzing the physics concepts related to bamboo spinning top phenomena and designing the integrated e-module. The analyzed concepts included rotational motion, torque, precession, nutation, drag force, and the Magnus effect. Furthermore, the e-module structure, material presentation flow, visual appearance, and integration between PDF-based materials and Google Sites were designed. Multimedia elements such as illustrations, experimental videos, simulations, and interactive navigation were also developed to support contextual learning experiences.

The develop stage was conducted through expert validation and revision processes. Validation was carried out by material experts and media experts to evaluate content quality, material presentation, visual design, interactivity, and media integration. After the validation process, the e-module was revised based on suggestions and feedback provided by the validators.

The disseminate stage was conducted on a limited scale through the dissemination and implementation of the developed e-module to students who had completed mechanics courses. At this stage, student responses were collected to evaluate the readability, usability, usefulness, and attractiveness of the developed learning media.

Results and Discussion

Characteristics of the Developed E-Module

The developed product was an integrated ethnophysics e-module for mechanics learning using Indonesian bamboo spinning tops as the context for physics learning. The e-module was developed by integrating PDF-based materials and Google Sites within a connected digital learning environment. The main characteristics of the e-module included the integration of PDF and Google Sites, the use of ethnophysics contexts based on bamboo spinning tops, the implementation of the Magnus effect approach in spinning top motion analysis, and the presentation of learning materials through multirepresentation and interactive multimedia.

Integration of PDF and Google Sites

One of the main characteristics of the e-module was the integration between PDF and Google Sites within a single digital learning system. The PDF version was used to present learning materials systematically and structurally, while Google Sites functioned as an interactive platform providing multimedia elements such as experiment videos, motion illustrations, simulations, and additional learning resources. The integration between the two platforms was implemented through hyperlinks and QR codes, allowing users to switch between the main materials and the interactive digital content. The homepage display of the integrated ethnophysics e-module is presented in Figure 2.

Figure 2. Homepage of the Integrated Ethnophysics E-Module

The homepage of the e-module was designed with simple and structured navigation. The homepage provided access to mechanics materials, experiment videos, spinning top motion visualizations, practice exercises, as well as integrated access to the PDF version and Google Sites pages. The developed e-module is publicly accessible through the Google Sites platform at https://sites.google.com/students.unnes.ac.id/e-modul-analisis-gerak-gasing/home.

The materials in the e-module could be accessed through various digital devices. The integration between the PDF version and Google Sites through a QR code provided on the e-module cover is presented in Figure 3.

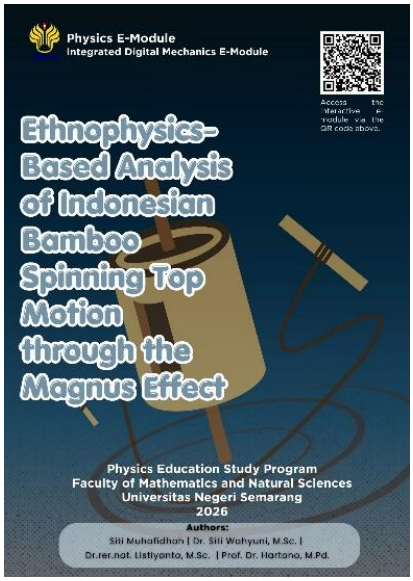


Figure 3. PDF and Google Sites Integration

The positive media validation results indicated that the integration between PDF and Google Sites was considered appropriate in terms of visual appearance, readability, accessibility, and navigation. This finding was supported by the high validity scores obtained in the aspects of media design and appearance (85.00%), language and readability (83.33%), and accessibility and navigation (86.67%), all of which were categorized as highly valid. In addition, the highly positive student responses suggested that the integrated digital environment supported usability and readability during learning activities. These findings indicated that the use of interconnected digital platforms contributed to the feasibility and acceptance of the developed e-module in mechanics learning that was in line with Ratna (2025).

Ethnophysics Context

Another characteristic of the e-module was the implementation of an ethnophysics context through the use of Indonesian bamboo spinning tops as a contextual representation of mechanics concepts. Bamboo spinning tops are traditional games commonly found in several regions of Indonesia, particularly Yogyakarta and Central Java, and are closely related to rotational dynamics concepts in physics. The use of bamboo spinning tops as a learning context enabled mechanics concepts to be presented through observable cultural phenomena that are familiar to students. The traditional Indonesian bamboo spinning top used as the ethnophysics context in the developed e-module is presented in Figure 4.

Figure 4. Traditional Indonesian Bamboo Spinning Top

The motion of bamboo spinning tops was used to represent several mechanics concepts, including rotational motion, torque, moment of inertia, precession, nutation, drag force, and the Magnus effect. Through this contextual representation, abstract mechanics concepts could be connected with real-world phenomena encountered in local culture. The high material validation results indicated that the ethnophysics context implemented in the developed e-module was considered appropriate for supporting the presentation of mechanics concepts. This interpretation was supported by the high scores obtained in the aspects of material suitability with the objectives and focus of the study (93.33%), accuracy and consistency of physics concepts (91.67%), and integration between mathematical concepts and physical phenomena (88.33%). These findings are consistent with the results reported by Fiskawarni *et al.* (2025).

Multirepresentation Mechanics Materials

In addition to conceptual explanations, the e-module was also equipped with visual illustrations, mathematical equations, motion analysis, and visualizations of physics phenomena related to bamboo spinning top motion. The mechanics materials were presented through combinations of verbal, visual, mathematical, and contextual representations so that physics concepts could be displayed in various forms of learning representation. One example of ethnophysics-based mechanics materials presented in the e-module was shown in Figure 5.

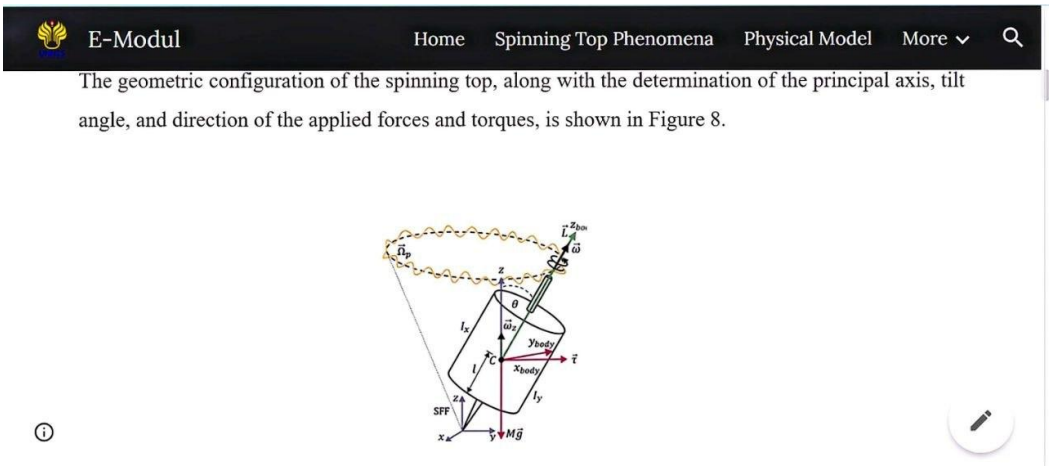


Figure 5. Illustration of Spinning Top Geometry and Force Configuration

The positive material validation results and student responses indicated that the presentation of multirepresentation materials supported conceptual understanding and the clarity of learning materials in the developed e-module. This finding was supported by the high validation scores in the aspects of accuracy and consistency of physics concepts (91.67%) and material suitability with students' conceptual understanding (85.00%), as well as the positive student responses regarding clarity and presentation of materials (86.90%). These findings are consistent with those reported by Arifiana *et al.* (2025).

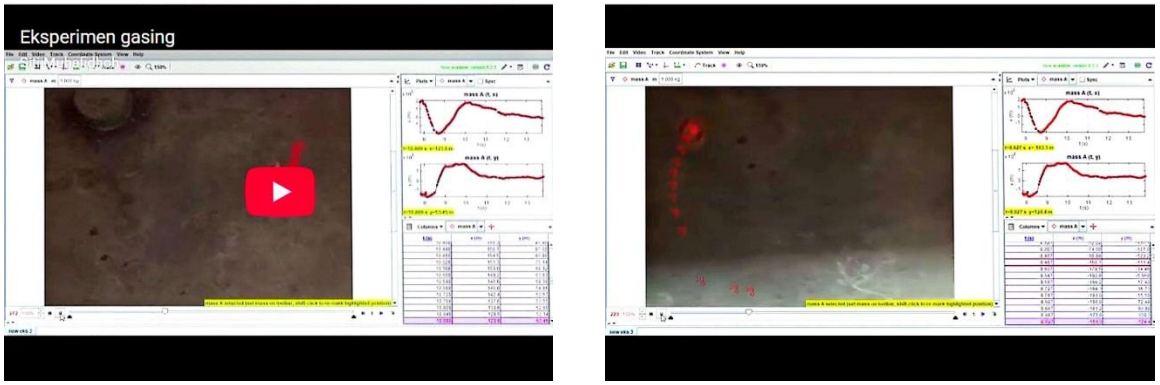
Interactive Multimedia Features

Another characteristic of the e-module was the presentation of learning materials through multirepresentation and interactive multimedia. The e-module was equipped with several supporting learning features, including motion analysis illustrations, mechanics concept visualizations, experiment and computation activities, assessment tasks, and interactive navigation between learning sections. These features were organized through several menu tabs within the Google Sites platform, allowing users to access different learning resources systematically. The navigation features provided in the developed e-module are presented in Figure 6.

Figure 6. E-Module Navigation Features

The navigation system consisted of several interconnected menu tabs, including *Spinning Top Phenomena*, *Physical Model*, *Experiments & Computation*, and *Assessment*. This structure enabled students to access learning materials, mechanics visualizations, experiment activities, computational analyses, and evaluation tasks through a single integrated digital environment.

One of the multimedia features integrated into the e-module was an embedded experiment video, as presented in Figure 7. Figure 7(a) shows the embedded experiment video that could be accessed directly through the Google Sites page, while Figure 7(b) shows the playback of the same video presenting bamboo spinning top motion analysis using the Tracker application.



(a) (b)

Figure 7. (a) Embedded Experiment Video on the Google Sites Platform and (b) Bamboo Spinning Top Motion Analysis Using the Tracker Application**.**

The integration of experiment videos in the e-module was used to present visualizations of mechanics concepts through real motion phenomena. Ethnophysics-based mechanics materials in the e-module were presented through the integration of bamboo spinning top motion phenomena with physics concepts using combinations of text, illustrations, visualizations, multimedia elements, and motion analysis integrated within the PDF materials and Google Sites.

The positive media validation and student response results indicated that the multimedia features supported the attractiveness, usability, and readability of the developed e-module. Evidence for this interpretation can be seen in the high scores obtained for media design and appearance (85.00%) and accessibility and navigation (86.67%) in the media expert validation, as well as the positive student responses

in the aspects of ease of use (94.20%), usefulness (88.69%), and appearance and readability (91.22%). In addition, the integration of Tracker-based motion analysis provided opportunities for students to observe spinning top motion phenomena dynamically through digital visualization. These findings suggest that the integration of interactive multimedia features contributed to the development of a more visual and contextual mechanics learning environment.

Expert Validation Results

Material Expert Validation

The material expert validation results showed that aspect A, namely material suitability with the objectives and focus of the study, obtained the highest percentage of 93.33%. Aspect B, namely the accuracy and consistency of physics concepts, obtained a percentage of 91.67%. Meanwhile, aspect C related to material suitability with students' conceptual understanding obtained a percentage of 85.00%, and aspect D related to the integration between mathematical concepts and physical phenomena obtained a percentage of 88.33%. All assessment aspects were categorized as highly valid. Overall, the material expert validation results showed an average percentage of 89.58%, indicating that the developed e-module met the criteria for use in mechanics learning. The e-modul validation results by material expert is presented in Figure 8.

Figure 8. Material Expert Validation Results

Based on the validation results, the developed e-module was considered systematically organized and aligned with the objectives and focus of the study. The highest percentage obtained in aspect A indicates that the developed e-module successfully maintained consistency between the mechanics materials presented and the objectives and focus of the study. This finding suggests that the integration of ethnophysics contexts and mechanics concepts was considered appropriate for supporting contextual mechanics learning. A similar result was reported by Rodiah *et al.* (2025) who found that ethnophysics-based learning materials can enhance the contextualization of physics concepts in learning activities.

The high percentage obtained in aspect B also indicates that the mechanics concepts presented in the e-module were considered accurate and conceptually consistent. The developed e-module integrated several mechanics concepts, such as rotational motion, torque, moment of inertia, precession, nutation, drag force, and the Magnus effect through the context of Indonesian bamboo spinning top motion. This result suggests that the ethnophysics context did not reduce the scientific accuracy of the learning materials, but instead provided contextual representations that supported the presentation of physics concepts within observable physical phenomena (Irfandi *et al.*, 2023).

In addition, the high percentage obtained in aspect D indicates that the developed e-module successfully integrated mathematical representations with physical phenomena. The use of geometry

illustrations, force configurations, motion analysis, and mathematical equations in the e-module demonstrated that mechanics concepts were presented through combinations of mathematical and visual representations. This finding suggests that the bamboo spinning top context successfully represented the mechanics concepts discussed in the developed e-module.

Although aspect C obtained the lowest percentage among all assessment aspects, the result still fell within the highly valid category. This finding indicates that the developed learning materials were considered appropriate for supporting students' conceptual understanding in mechanics learning. The use of multirepresentation materials, contextual explanations, experiment videos, and motion visualizations may contribute to help students understand mechanics concepts through various forms of representation rather than through abstract mathematical formulations alone.

Media Expert Validation

The media expert validation results showed that aspect A, namely media design and appearance, obtained a percentage of 85.00%. Aspect B, namely language and readability, obtained a percentage of 83.33%, while aspect C, namely accessibility and navigation, obtained the highest percentage of 86.67%. All assessment aspects were categorized as highly valid. Overall, the media expert validation results showed an average percentage of 85.00%, indicating that the developed e-module fulfilled the criteria for interactive digital learning media in mechanics learning. The media expert validation results are presented in Figure 9.

Figure 9. Media Expert Validation Results

Based on the validation results, the developed e-module was considered to have appropriate visual design, readability, and accessibility for supporting digital learning activities. The highest percentage obtained in aspect C indicates that the accessibility and navigation features of the e-module were considered effective in supporting students' learning activities. These findings indicated that the integration between PDF and Google Sites through hyperlinks and QR codes enabled students to move flexibly between structured learning materials and interactive multimedia content, which was in line with the findings of Waang (2023). This finding suggests that the developed e-module successfully created a connected digital learning environment that could be accessed through various digital devices and supported flexible learning activities.

In addition, the high percentage obtained in aspect A indicates that the visual design and appearance of the e-module were considered appropriate for supporting mechanics learning. The use of structured layouts, motion illustrations, mechanics visualizations, experiment videos, and interactive multimedia elements contributed to creating a more engaging learning environment. The integration of

ethnophysics contexts through bamboo spinning top phenomena also supported the visual presentation of mechanics concepts through observable physical representations.

Although aspect B obtained the lowest percentage among the assessment aspects, the result still fell within the highly valid category. This finding indicates that the language and readability aspects of the e-module were considered understandable and appropriate for learning activities. The use of contextual explanations, combinations of verbal and visual representations, and systematic presentation of materials may support students in understanding mechanics concepts more effectively (Malinova & Mendling, 2021). Several revisions suggested by the media experts, such as improving visual consistency, refining multimedia components, and optimizing navigation, were also conducted to improve the usability and accessibility of the developed e-module.

Student Response Results

The student response results showed that aspect A, namely ease of use, obtained the highest percentage of 94.20%. Aspect B, namely clarity and presentation of materials, obtained a percentage of 86.90%, while aspect C, namely usefulness, obtained a percentage of 88.69%. In addition, aspect D, namely appearance and readability, obtained a percentage of 91.22%. All assessment aspects were categorized as very positive. Overall, the student response results showed an average percentage of 90.25%, which was categorized as very positive. These results indicate that the developed ethnophysics e-module received positive responses from students and was considered appropriate for supporting mechanics learning activities. The student response results are presented in Figure 10.

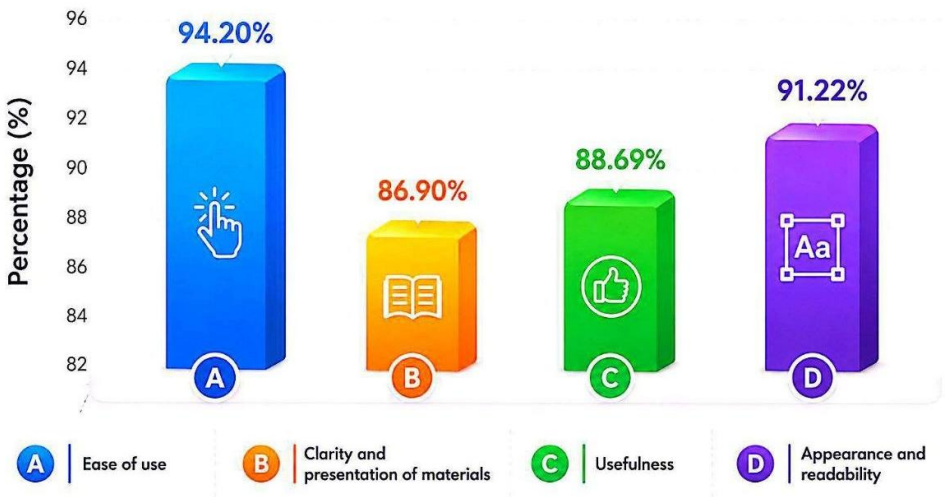


Figure 10. Student Response Results

Based on the student responses, the developed e-module was considered easy to use and accessible during learning activities. The student response results indicate that the developed ethnophysics e-module received highly positive responses from students and was considered appropriate for supporting mechanics learning activities. The high average percentage obtained from the student responses suggests that the developed e-module was able to support learning activities through the integration of contextual mechanics materials, interactive multimedia, and flexible digital access. These findings indicate that the integration between PDF materials and Google Sites contributed to creating a learning environment that was considered practical and engaging for student (Yang & Baldwin, 2020).

The highest percentage obtained in aspect A indicates that the developed e-module was considered easy to use during learning activities. The integration between PDF materials and Google Sites through hyperlinks and QR codes enabled students to access learning materials, experiment videos, motion visualizations, and additional resources more flexibly. This result suggests that the developed digital learning

environment successfully supported students in accessing mechanics learning materials through various digital devices without being limited by time and place.

In addition, the high percentage obtained in aspect D indicates that the appearance and readability of the e-module were considered attractive and appropriate for supporting learning activities. The use of structured layouts, illustrations, visualizations, experiment videos, and multimedia elements may contribute to increasing students' interest and engagement during mechanics learning (Chisunum & Nwadiokwu, 2024). The integration of ethnophysics contexts through bamboo spinning top phenomena also provided more observable and contextual representations of mechanics concepts, which may help students connect theoretical concepts with real physical phenomena.

The results obtained in aspect C also indicate that the developed e-module was considered useful for supporting students' understanding of mechanics concepts. The use of multirepresentation materials, motion analysis, experiment videos, and contextual explanations may help students understand mechanics concepts through combinations of verbal, visual, mathematical, and contextual representations. Although aspect B obtained the lowest percentage among the assessment aspects, the result still fell within the very positive category. This finding indicates that the presentation of materials and language used in the e-module were considered sufficiently clear and understandable for learning activities.

Conclusion

Based on the results and discussion, it can be concluded that (1) The main characteristics of the developed e-module included integration of PDF and Google Sites, ethnophysics context, multirepresentation mechanics materials, interactive multimedia features, (2) the developed e-module fulfilled the criteria for highly valid learning media based on material expert and media expert validation results, and (3) the developed e-module received highly positive responses from students in terms of ease of use, material presentation, usefulness, appearance, and readability. The integration of ethnophysics contexts and interactive digital learning features indicates the potential of the developed e-module to support contextual and interactive mechanics learning.

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