# Science Process Skills-Based E-Module for Earth and Space Science Class: A Supplemental Teaching Resource of NAAP Basic Coordinates and Seasons Simulator

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**Abstract.** Living in this interconnected world, students require having science process skills. The study of science process skills-based instructional material has been on the rise for the last decade. Yet there are few regarding the developing science process skills-based electronic module (e-module) for higher-education Earth and Space Science Classes. This study aims to overcome these limitations by developing a science process skills-based e-module as a supplemental teaching resource of NAAP basic coordinates and seasons simulator. The development of e-module refers to the 4-D research and development model. This study intends to look into (1) how to design the science process skills-based astronomy e-module, 2) how is the validity of the e-module. For a better result, the e-module was assessed by three validators through an online questionnaire, including content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, and interaction usability. Results revealed that the science process skills-based e-module was categorized as valid. Based on the research, it can be concluded that the developed e-module can be considered suitable for implementation in earth and space science learning. As a further recommendation, this e-module needs to be tested for its effectiveness in influencing students' scientific process skills or not.

**Keywords:** e-module, earth and space science, science process skills, naap virtual laboratory.

## Introduction

The development of science and technology that has occurred up to the present is the result of individuals' curiosity, which begins with questions of what, why, and how after observing a phenomenon. This curiosity is then investigated through science inquiry, leading to knowledge acquisition, and potentially evolving into a technological product. As part of science, the knowledge that makes up Physics also begins with the process of scientific inquiry. It is known that physics has the essence of a product, a process, and an attitude [1]. Physics as a process is related to how scientists work to obtain the knowledge that constitutes physics[2]. The acquisition of such knowledge is a way of


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investigating or scientific inquiry, carried out using skills such as observation, measurement, asking questions, drawing conclusions, and other skills. The skills that scientists must possess in scientific inquiry are called science process skills [3].

Science Process Skills (SPS) are categorized into basic SPS and integrated SPS [4–6]. Some researchers further break down this categorization into different SPS indicators. However, the essence of this classification is the same: basic SPS must be mastered first to master more complex SPS (integrated SPS). In a more in-depth analysis, [7] illustrate the SPS diagram as seen in Fig. 1. The skills at the bottom are the basic SPS, which include observing, inferring, classifying, measuring, communicating, and predicting. Meanwhile, integrated SPS includes identifying variables, constructing hypotheses, defining operational variables, constructing data tables, constructing graphs, obtaining, and processing data, designing investigations, analyzing investigations, describing the relationship between variables, and conducting experiments.

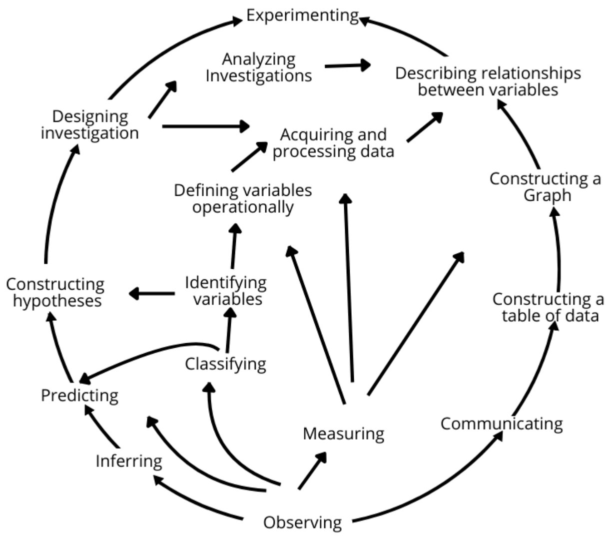


**Fig. 1.** Diagram of Science Process Skills

According to Sutrisno [8], learning physics as a process should aim to successfully develop SPS in students. The importance of cultivating SPS in physics education is because SPS is a crucial skill that students should possess. Özgelen (2012) states that SPS supports students' thinking, reasoning, inquiry, evaluation, problem-solving, and creativity. Regarding the mastery of concepts, SPS also supports the achievement of science concept mastery and its applications [3]. Given the importance of cultivating SPS in education, physics teachers should ideally understand the essence of SPS to prepare SPS-based learning for their students. To train teachers who understand SPS, one way to achieve this is to cultivate SPS in prospective teacher students. According to [9], prospective teachers should possess SPS so that when they become actual teachers, they have a sufficient understanding of SPS and can apply it in classroom teaching.

Additionally, conventional teaching methods may occur because teachers lack of SPS [10].

Regarding the SPS of prospective teacher students, according to Mahmudah et al [11], the development of SPS in these prospective teacher students at the Department of Physics Education Siliwangi University through the course of Earth and Space Science still needs further optimization. Based on their findings, 22.6% of students have science process skills categorized as less than good. The limitations of educators in cultivating SPS in students are a factor that influences the development of SPS in these students. Learning activities facilitating SPS in the Earth and Space Science course have been implemented. For instance, in the topic of the earth revolution, SPS is cultivated through lecturer demonstration using virtual simulation The Nebraska Astronomy Applet Project (NAAP) Lab Basic Coordinates and Seasons. This activity provides prospective teacher students the opportunity to observe phenomena through demonstrations. However, the learning activity of training science process skills still to be optimal because the designed learning process does not allow students to independently explore phenomena through NAAP-Lab simulations. Also, there is a lack of teaching materials related to the earth revolution that would support educators in optimizing the cultivation of SPS.

Based on a further study analysis conducted among prospective physics teacher students who have taken the Earth and Space Science course at the Department of Physics Education, Siliwangi University, 89% of them have previously used the NAAP-Lab simulations on basic coordinates and seasons. However, in their learning process, students must be provided with teaching materials that facilitate their science process skills, whether in content presentation, learning activities, or assessment tools. Therefore, 97% of prospective physics teacher students agree that learning requires teaching materials in modules that package content, learning activities, and assessment tools that cultivate their science process skills. Regarding module type, 80% of prospective physics teacher students require an electronic module that can be accessed using a smartphone or PC.

Several studies on how to cultivate SPS for prospective physics teachers have been conducted, including the use of Diagram I media [5] ;experiment-based learning [12–15]; the implementation of the CCDSR model [16]; and project-based outdoor learning [17]. However, research and development of science process skills-based modules on basic coordinates and seasons have not been conducted yet.

Given the importance of science process skills for prospective teacher students and the fact that the teaching materials used in Earth and Space Science education on the topic of earth revolution do not yet cultivate these skills, there is a need for research and development about science process skills-based e-module for earth and space science class as a supplemental teaching resource of NAAP basic coordinates and seasons simulator. Based on these needs, this study intended to develop a science process skills-based e-module for earth and space science class as a supplemental teaching resource of NAAP basic coordinates and seasons simulator.

## 2 Methodology

In developing the integrated NAAP-labs e-module to train students' science process skills on basic coordinates and seasons, the researcher used the Research & Development (R&D) method with the 4D development model consisting of four main stages: define, design, develop, and disseminate [18]. In this study, the development stages were limited to the "develop" stage. The complete research and development stages are presented in Fig. 2.

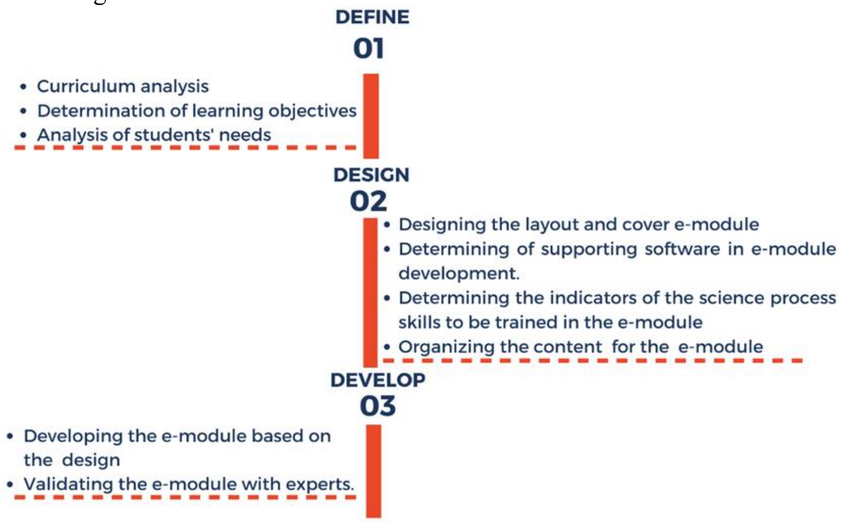


**Fig. 2.** Research and development stages took in this study.

The instruments used in this research consist of a questionnaire instrument for needs analysis and the LORI instrument to validate the developed e-module. The needs analysis questionnaire is used to determine the urgency of the e-module needs, covering aspects such as analyzing difficulties in the content, the required format of the e-module, and an analysis of the use of available technology tools. A Guttman scale questionnaire distributed to students via the Qualtrics website. Respondents are students who have already enrolled in the earth and space science course. On the other hand, the instrument used for validation is the Learning Object Review Instrument (LORI), developed by [19]. The indicators assessed in the LORI instrument include content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, and interaction usability. The LORI instrument takes the form of a Likert scale questionnaire consisting of four categories: 1 (irrelevant), 2 (somewhat relevant), 3 (sufficiently relevant), 4 (relevant), and 5 (highly relevant). In addition to providing scores on the scale, validators are also asked to give feedback or suggestions for the prototype in the space provided at the end of the questionnaire. The validity scores experts gave were calculated using [20], as shown in Equation (1).

$$V = \frac{\sum s}{n(c-1)} \tag{1}$$

In the equation, the value V represents the validity score, s represents the difference between the expert and lowest scores, n represents the number of experts (evaluators), and c represents the highest value on the scale. Then, the e-module will be considered as a valid product whe the validity score meets the minimum validity value requirements depending on the number of evaluators and rating categories, as shown in Table 1.

**Table 1.** Aiken minimum validation values

| Item no. | Number of rating categories | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Evaluator | 3 | | 4 | | 5 | | 6 | | 7 | |
| (n) | V | p | V | p | V | p | V | p | V | p |
| 2 | | | | | 1.00 | 0.040 | 1.00 | 0.028 | 1.00 | 0.02 |
| 3 | | | | | 1.00 | 0.008 | 1.00 | 0.005 | 1.00 | 0.003 |
| 3 | 1.00 | 0.037 | 1.00 | 0.016 | 0.092 | 0.32 | 0.87 | 0.046 | 0.89 | 0.029 |
| 4 | | | 1.00 | 0.004 | 0.94 | 0.008 | 0.95 | 0.004 | 0.92 | 0.006 |
| 4 | 1.00 | 0.012 | 0.92 | 0.020 | 0.88 | 0.024 | 0.85 | 0.027 | 0.083 | 0.029 |

# 3 Result and Discussion

## 3.1 Define Stage

In the define stage, the researcher carries out several activities to determine and define the requirements in the development process. These activities include curriculum analysis and conducting an analysis of the students' needs for the e-module. The results of the analysis are used as a reference in developing an e-module to enhance Students' Science Process Skills on Earth Revolution. The results of curriculum analysis and learning objectives are given in Table 2.

**Table 2.** Curriculum Analysis Result

| Analized Aspect | Description |
|---|---|
| Learnig Outcome (LO) | The LO for PA1 (cognitive): Students are able to master the theoretical concepts of classical and modern (quantum) physics in general.<br>The LO for S9 (affective): Demonstrating a responsible attitude towards work in one's field of expertise independently.<br>The LO fo KU1 (skills): Students are capable of applying logical, critical, systematic, and innovative thinking in the |

| Analized Aspect | Description |
| --- | --- |
| | context of developing and implementing science and technology while considering and applying humanistic values relevant to the field of physics.<br>The sub-LO: Students are able to analyze the motion and positions of celestial objects and develop independent reasoning skills. |
| The use of teaching materials commonly used to fulfill CPL (Learning Outcome Achievement) requirements. | In achieving the CPL assigned to Sub-CPMK-3, learning about the Earth's revolution is conducted through lectures and demonstrations using virtual simulations from NAAP-Labs on Basic Coordinates and Seasons. |

Based on the analysis of sub-learning outcomes to meet the learning outcomes to support the optimal implementation of science process skill training activities, teaching materials are required that contain supporting content, activity for independent exploration, and appropriate assessment tools. Therefore, a teaching module based on science process skills that integrates virtual simulations from NAAP-Labs is needed. Then, the analysis of students' needs is shown in Table 3.

**Table 3.** Students' need analysis result.

| Aspect | Description |
| --- | --- |
| Analysis of material difficulties in the topic of earth revolution | 49% of students have difficulty visualizing the tilt of the Earth's axis relative to the ecliptic plane, 10% of students have difficulty visualizing the differences in light intensity received by regions with different latitudes throughout the year, 16% of students have difficulty visualizing the duration of daylight and nighttime received across the entire globe throughout the year, and 9% of students have difficulty visualizing the phenomenon of the midnight sun. |
| Required format of the e-module | 94% of prospective teacher students need teaching materials that contain learning guides for studying the Earth's revolution using NAAP-Lab simulations.<br>98% of prospective teacher students need teaching materials that provide supporting content for the Earth's revolution.<br>80% of students require activity guides that provide opportunities for self-directed learning.<br>79% of prospective teacher students need teaching materials in electronic format. |
| Use of available technology tools | 100% of students have devices capable of oper-ating electronic teaching materials. |

Based on the needs analysis conducted in the define stage, it is necessary to create an e-module with the following specifications: (1) A module comprising content and guides for exploring simulations. (2) A module that facilitates students in independently exploring the content. (3) An electronic module. (4) A module that is easily accessible using both PCs and mobile phones.

### 3.2 Design Stage

Based on the need analysis at the beginning of the first stage, there was science process skill-based e-module development needed. The basis for determining e-modules as teaching materials to be developed is the diagram proposed [21], as shown in Fig. 3. The learning activities are designed so that students can actively construct concepts through stages of science process skills. During the learning activities, all students certainly need learning resources as sources of learning information. These learning resources contain learning materials, laboratory practice guidelines, and formative tests. Along with the advancement of information technology, teaching materials used in the learning process also evolve and innovate for the progress of education. Therefore, e-module become one of the teaching materials that can be considered.

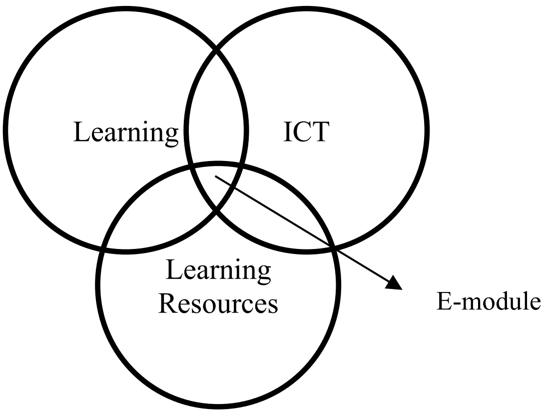


**Fig. 3.** Diagram of Relation of Learning, ICT, and Learning Resources

At this stage, the activities divided into two parts, there were determining the outline of the e-module, determining of supporting software in e-module development, determining the indicators of the science process skills to be trained in the e-module, and organizing the content for the e-module. This stage started with designing the outline, as shown in Fig. 4. This stage continued with determining supporting tools for designing the e-modul, there were online Canva for designing content of th e-module, and online Heyzine for converting a PDF file into an online flipbook. The indicators trained in the e-module are basic science process skill indicators, including observing, communicating, and classifying.

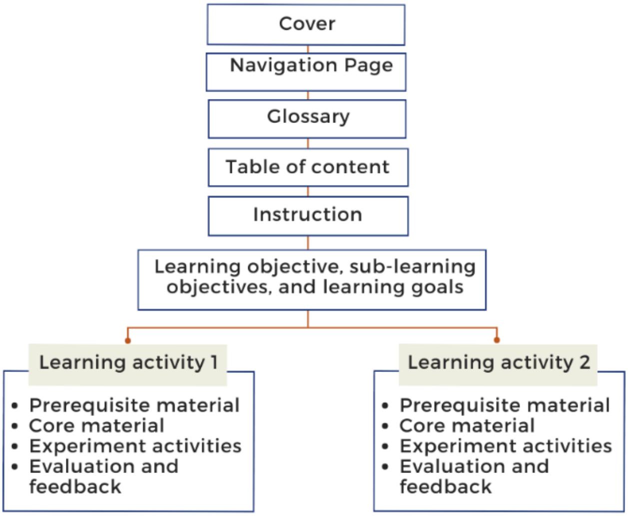


**Fig. 4.** Outline of e-module

## 3.3 Develop Stage

Turning the listed ideas into a product was began at the development stage. At this stage, the activities divided into two parts, there were developing e-modul based on the previous design and validating e-module with expert. The display of the developed e-module can be seen in Fig. 5.

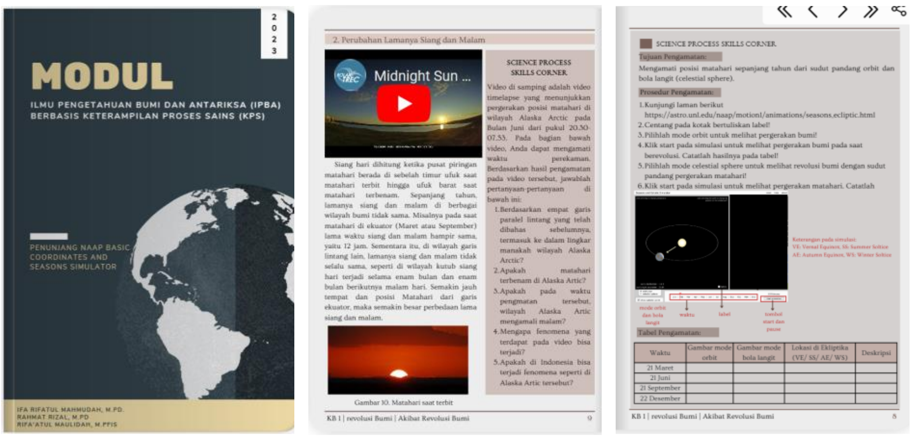


**Fig. 5.** Example of page displays of the e-module

To produce a better e-module, expert validation is necessary. Therefore, using the LORI instrument, three validators validated the developed e-module. The summary of expert validation results is presented in Table 4.

**Tabel 4.** Summary of expert validation to the e-module

| Evaluator | Content quality | | Learning goal alignment | | Feedback and adaptation | | Motivation | | Presentation design | | Interaction usability | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | s | R | s | R | s | R | s | R | s | R | s |
| 1 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 3 |
| 2 | 4 | 3 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 |
| 3 | 5 | 4 | 5 | 4 | 5` | 4 | 5 | 4 | 5 | 4 | 5 | 4 |
| $\sum s$ | 10 | | 11 | | 12 | | 11 | | 11 | | 11 | |
| V | 0,83 | | 0,92 | | 1,00 | | 0,92 | | 0,92 | | 0,92 | |

Based on the summary of validation results in Table 4, an average validity score of 0.92 was obtained. This score meets the minimum validity threshold. In addition to providing ratings, each validator also offered corrections and suggestions on the developed e-module, including suggestions for adding a short link for easier access, adding content related to climate classification and climate change, and providing more comprehensive image captions.

Regarding content quality, validators provided scores of 4 to 5, indicating that the developed e-module's content is almost error-free, presented without bias, and applicable for various types and levels of learners. For learning goal alignment, validators gave scores of 4 to 5, signifying that learning goals are clearly defined in the e-module, suitable for the intended learners, and aligned well with the learning activities, content, and assessments provided. The learning objectives are designed to meet the course's learning outcomes. The chosen learning activities for achieving these objectives and training science process skills are laboratory-based activities. Laboratory activities are important for students as they help build their experiences, understand science concepts, develop problem-solving skills, foster cooperation, and enhance science process skills (Bolat et al., 2014). This is in line with Salamah & Mursal [22] that practicum is the best learning method for developing science process skills because learning with practicum can provide opportunities for students to act directly in an activity that proves a theory. This e-module was designed to provide a virtual laboratory-like learning experience. In the sub-topic of latitude and longitude, prospective teacher students can observe the positions of different countries and classify them based on four parallel lines of latitude. In the topic of Earth's revolution, prospective teacher students can observe phenomena related to the Earth's revolution through the virtual NAAP Lab simulation. As a result of these observations, prospective teacher students can describe and explain how the Earth's position changes relative to the Sun throughout the year, both in terms of its orbit and the celestial sphere framework. In the topic of the consequences of Earth's revolution, prospective teacher students can gather data on the duration of daylight and nighttime in specific regions and then create tables and interpret how the length of day and night varies in different parts of the Earth.

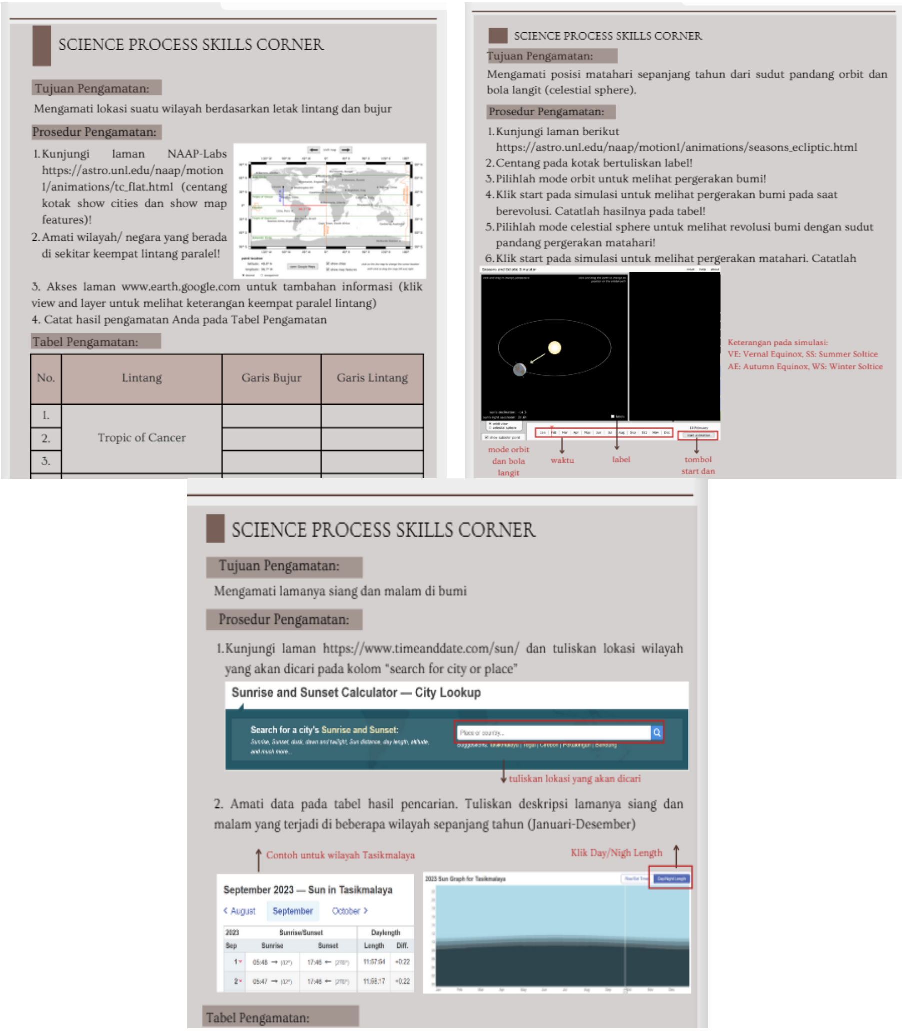


**Fig. 6.** science process skills-based laboratory activities in the e-module

In terms of feedback and adaptation, validators provided scores in the range of 4 to 5, indicating that the developed e-module meets the following criteria: the ability to customize activities based on the learner's needs, the capability to modify phenomena under study in response to varying input from the learner, and the presence of feedback on student responses. Regarding motivation, validators gave scores in the range of 4 to 5, signifying that the developed e-module is highly motivating, its content is relevant to the interests of the intended learners, and the e-module offers real-life learning activities and interactivity. In terms of presentation design, validators scored in the range of 4 to 5, indicating that the e-module's design allows users to learn efficiently, the text is legible, graphs and charts are labeled and free from clutter, headings clearly signal the content of text passages, the writing is clear, concise, and error-free, and the use of color and decorative features is aesthetically pleasing.

For interaction usability, validators scored in the range of 4 to 5, indicating that the e-module's user interface design implicitly guides learners on how to interact with the object, navigation through the module is easy, intuitive, and nearly free from excessive delays. Electronic modules are more interactive in nature because users can easily access parts of the module through conveniently provided buttons. According to Welsh et al. [23], electronic modules are more effective than printed modules. Through ICT-based learning, various multimedia services can be easily transferred, such as high-resolution audio, video, and graphics, thus engaging the thinking process [24].

## 4 Conclusion

Results revealed that the science process skills-based e-module was categorized as valid. Based on the research, it can be concluded that the developed e-module can be considered suitable for implementation in earth and space science learning. The study highlighted the need for better teaching materials that train science process skills in the Earth and Space Sciences course. In summary, a science process skills-based e-module for earth and space science class as a supplemental teaching resource of NAAP basic coordinates and seasons simulator developed as planned using 4D. As a further recommendation, this e-module needs to be tested for its effectiveness in influencing students' scientific process skills or not.

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