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Development of an Agrophysics E-Module as Teaching Materials for Supporting Sustainable Industrial Agriculture

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Abstract: This study aims to develop an Agrophysics e-module using the Articulate Storyline application and to evaluate its validity and feasibility as a teaching material to support sustainable industrial agriculture. A research and development method based on the 4D model was employed, encompassing the define, design, and develop stages. The research instruments included material and media expert validation sheets as well as user response questionnaires. Validation was conducted by three experts, and user trial responses were collected from 28 students. The data were analyzed using descriptive statistical techniques. The results of the material expert validation yielded an average score of 3.63, categorized as highly feasible, while media validation produced an average score of 3.33, also classified as highly feasible. Preliminary trial results indicated user responses with an average score of 3.70, falling within the highly feasible category. Consequently, the Agrophysics e-module was deemed feasible for use as a teaching material. The module was designed to integrate recent developments in the application of physics concepts in agriculture. Therefore, the developed e-module contributes to multidisciplinary physics learning within the context of supporting sustainable industrial agriculture.

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Introduction

Agrophysics is defined as the scientific discipline that applies the principles of physics to the field of agriculture. The field of agrophysics focuses on the physical properties and processing of materials, as well as on agricultural systems that support high-quality, efficient, and environmentally safe production. Agrophysics research offers the possibility of reducing chemical and physical degradation of soil, reducing product losses during harvesting, post-harvest, and storage processes, and improving the quality of food and agricultural products (Dobrzański et al., 2016; Gliński et al., 2013).

Soil is defined as a dynamic and heterogeneous system formed by the weathering of minerals and the decomposition of organic matter (Shoumik & Khan, 2024). It functions as a medium for plant growth. Soil fertility constitutes a pivotal component within the domain of agriculture. Consequently, there exists a necessity for a comprehensive understanding of the methodologies involved in the maintenance and enhancement of soil fertility, thereby ensuring optimal plant growth (Kenjaev & Aripov, 2024). Soil fertility indicators encompass chemical indicators such as pH and physical indicators including water content, soil texture, porosity, permeability, structure, and bulk density (Hartanto & Wicaksono, 2022). In addition

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to the parameters mentioned above, physical parameters such as resistivity or conductivity values can also be used (Kahfi & Pohan, 2023).

Much research has been conducted on the analysis of soil physical properties. For example, research related to the analysis of soil physical properties in the Jatirono cocoa plantation in Banyuwangi Regency. The results of the study explain that the soil texture is sandy loam with medium-high bulk density and fairly fast permeability, causing low water retention, which has an impact on the suboptimal growth of cocoa plants in the Jatirono Banyuwangi plantation (Salsabila et al., 2025).

In addition, research using physical parameters such as resistivity has also been conducted extensively. For example, research by (Ganiyu et al., 2020) shows that this method can be used to identify soil types and water content in the soil. In another study by (Fagbemigun et al., 2021), it was found that this method is effective for determining which soils can support optimal crop production and variations in soil water content at shallow depths. The resistivity method can also be used to determine the effect of rice husk biochar and compost fertilizer mixtures on soil fertility, which shows a pattern of decreasing resistivity values due to increased soil porosity and aggregation. (Pramudita et al., 2025).

Based on these research findings, they can be developed into teaching materials for the Agrophysics course. The results of these studies are generally only published in technical scientific journals and are not available in the form of structured teaching materials. In addition, the availability of textbooks and teaching materials that specifically discuss Agrophysics from a physics perspective is still limited. The existing literature is generally in the form of soil science or agronomy that emphasizes agricultural concepts, while basic physics concepts are still not discussed in depth. This makes it difficult for students to relate physics theory to agricultural applications. This condition shows a gap between research results and Agrophysics teaching materials. Therefore, teaching materials such as interactive e-modules are needed to integrate physics concepts in agriculture by presenting Agrophysics research.

The utilization of e-module has been demonstrated to enhance conceptual understanding (Fauza et al., 2023; Permata et al., 2021). E-module have been found to facilitate independence in learning (Haspen & Syafriani, 2022). The integration of e-module or digital module enables students to engage in learning at any location and at any time, thereby fostering their academic growth (Anggraeni & Prihandono, 2024). Furthermore, physics education does not merely emphasize definitions, knowledge, and understanding of concepts found in life (Arifuddin et al., 2022). In developing e-modules, Articulate Storyline can be used because it provides interactive features such as automatic feedback and adaptive navigation. The integration of multimedia such as images and videos also increases accessibility and student engagement in learning, especially in learning agrophysics.

A course in Agrophysics is a signature course in the Physics Education Program at the University of Jember. With the University of Jember's vision and mission related to sustainable industrial agriculture, the Physics Education Program supports these goals by designing this course. The description of the Agrophysics course is a course that applies physics concepts to solve or examine problems in the field of agriculture to support sustainable industrial agriculture. Specifically, this course discusses applied physics concepts in order to understand, analyze, and optimize the interaction between physical environmental factors and plants and soil..

Based on the background described above, it is necessary to develop an e-module that integrates physics concepts with industrial agriculture applications in a contextual and interactive manner. Therefore, this study aims to develop and test the feasibility of an

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Agrophysics e-module using Articulate Storyline to support sustainable industrial agriculture in particular and to support the vision and mission of the Study Program and the University in general.

Research Method

The present study constitutes a development study that employs the 4D model. The stages in this model consist of definition, design, and development. The dissemination stage of the 4D model was not included in this study, which exclusively focused on development and feasibility. At the definition stage, an analysis of the curriculum, needs, and characteristics of students and concepts was conducted. In addition, course outcome formulations were determined (Rahayu, 2025; Hariyanto et al., 2022; Muqdamien et al., 2021). The results of the student characteristics analysis show that students have a learning style that utilizes digital media and are accustomed to using smartphones for learning. In addition, students also have a weak understanding of concepts, so the e-modules are designed using a visual and interactive approach.

The design stage is characterised by the development of the product format, the selection of media, and the design of devices (Rahayu, 2025; Hariyanto et al., 2022). During the development stage, e-module are created, validated, revised, and tested on a limited basis (Utaminingsih et al., 2024; Hl, Nur Ihsan et al., 2023).

The instruments used in this study were expert validation sheets for materials and media, as well as user feasibility sheets during the trial. The research instruments, consisting of expert validation sheets for materials and media as well as user response questionnaires, were developed by the researchers by adapting indicators from teaching material validation instruments that had been used in previous studies (Aulianingsih et al., 2021; Doyan et al., 2022). Validation was carried out by three validators and user trial responses were collected from 28 students of the Physics Education Study Program. The sheets assessment was based on a Likert scale (1-4). The data was analysed descriptively in order to calculate the mean score for each aspect. The analysis technique aimed to determine the final score for each sheets item by dividing the total score obtained by the number of respondents who completed the assessment questionnaire (Pusparini & Sari, 2020). The resulting average scores were then converted qualitatively based on the criteria outlined in Table 1 below. This method will illustrate the feasibility results of the Agrophysics e-module. The values obtained are then converted quantitatively based on Table 1 below.

Table 1. Category criteria Agrophysics e-module

Average score	Category
$3.25<X\leq4.00$	Highly feasible
$2.50<X\leq3.25$	Feasible
$1.75<X\leq2.50$	Less feasible
$1.00<X\leq1.75$	Not feasible

(Widoyoko, 2016)

Results and Discussion

Research has been conducted on the development of an agrophysics e-module. The present study was grounded in the 4D model, yet it should be noted that solely the define, design, and develop stages were executed. This was due to the fact that the researchers' exclusive focus was on the development and feasibility of the model.

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Definition Stage

At this stage, learning requirements are defined and formulated as the basis for developing the Agrophysics e-module. The analysis conducted is a needs analysis for the Agrophysics e-module. In addition, student analysis and material analysis are conducted to ensure that the e-module is in line with the Course Learning Outcomes. Finally, assignments are analysed to determine the form of exercises and evaluations.

Design Stage

The objective of this stage is to produce the design for the Agrophysics e-module. The process entails the development of the e-module's structure, the design of the storyboard, the selection of media and format, and the design of instruments. The e-module is structured in the following way: an introduction, course objectives, materials, contextual examples of agrophysics, exercises, and evaluation. The storyboard is intended to establish the arrangement of text, images, and navigation buttons, in addition to delineating the user interaction flow. The subsequent stage in the process is the selection of the application to create the e-module. The present study employs Articulate Storyline due to its capacity to amalgamate interactive components with visual designs that facilitate readability and user comfort. At this final stage of the project, instruments were designed. These instruments included expert and user validation sheets and response questionnaires.

Development Stage

The objective of this stage is to produce a valid and usable Agrophysics e-module. The Agrophysics e-module was developed using the Articulate Storyline application, which was then converted into a mobile APK format. During the development stage, the material, images, exercises, and interactive evaluations were integrated, and the navigation buttons were set up. Subsequent to the completion of this stage, the product is then subjected to validation by subject matter experts, with the purpose of assessing the feasibility of the concepts. In addition, the product is then assessed by media experts, with the purpose of evaluating the appearance, design, and interactivity of the product. Subsequent to this, a usability test is conducted, with the test's parameters being material, graphics, language, and ease of use. Figure 1 shows an illustration of the developed media.

(a) (b)

Figure 1 (a) Interface of e-modul (b) Main menu of the e-module

1) Material Validation Result

The results of material validation are set out in Table 2. The assessment by material experts encompassed three aspects: content feasibility, presentation feasibility, and language feasibility.

Table 2. Material Validation Result

Assessment Aspect	Average Score	Category
Content feasibility	3.68	Highly feasible
Presentation feasibility	3.63	Highly feasible
Language feasibility	3.60	Highly feasible

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Average	3.64	Highly feasible

As demonstrated in the table, the content aspect received a score of 3.68, which is classified as highly feasible. The content aspect consists of indicators of the feasibility of the material with the Course Learning Objectives (CLOs) of the Agrophysics course, the accuracy of the material in the e-module, the currency of the material, and its ability to stimulate curiosity. Meanwhile, the presentation aspect received an average score of 3.63. This aspect consists of indicators of systematicity and logic in presentation, clarity and integration, visualisation quality, and consistency and readability of the e-module. Meanwhile, the language aspect scored 3.60, which is highly feasible, consisting of indicators of grammatical and spelling accuracy, clarity of meaning and readability of sentences, consistency of scientific terms, feasibility of language to the students' level of ability, and coherence of language with the scientific and academic cultural context.

Based on the results, the highest score was for content, which means that the content of this e-module is accurate and encourages the creation of knowledge for students, especially regarding agrophysics. Meanwhile, the language received the lowest score due to sentence structures that were not entirely correct according to language rules.

2) Media Validation Result

Media validation is assessed based on appearance and visual design, technical aspects, media integration with material, and appeal and creativity. The results are shown in Table 3.

Table 3. Media Validation Result

Assessment Aspect	Average Score	Category
Visual appearance and design	3.17	Feasible
Technical	3.50	Highly feasible
Media integration with material	3.17	Feasible
Attractiveness and creativity	3.50	Highly feasible
Average	3.34	Highly feasible

Concerning the visual aspect, the assessment indicators encompass such factors as layout feasibility, visual aesthetic quality, and clarity of illustrations and graphics. The technical aspect is evaluated based on indicators of user-friendliness, readability, format stability, and functionality. The integration of media with the subject material is characterised by three indicators: firstly, the media's feasibility with the characteristics of Agrophysics material; secondly, the media's feasibility with Course Learning Objectives (CLOs); and thirdly, the consistency of the presentation style. Conversely, the attractiveness and creativity aspect is comprised of indicators of visual presentation creativity and the ability to engender interest in learning. The aspects of visual appearance and design, technical aspects, media integration with material, and attractiveness and creativity received average scores of 3.17, 3.5, 3.17, and 3.5 respectively. Technical aspects and appeal-creativity received the highest scores because it is technically easy to use as students only need to access their smartphones and attractiveness and creativity because the media designed using Articulate Storyline makes it easy to design, which adds to the attractiveness of the e-module.

3) Students' Response

The responses of the users were based on aspects of content, language, ease of use, and graphics. The mean scores obtained were 3.70, 3.59, 3.88, and 3.63, respectively, thus yielding an average user response score of 3.70. It is evident from the results of this questionnaire sheet that the e-module can be regarded as being suitable for use in the context of agrophysics learning. The results are shown in Table 4 and can be observed visually in Figure 4.

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Table 4. Students' response result

Assessment Aspect	Average Score	Category
Content	3.70	Highly feasible
Language	3.59	Highly feasible
Utilization	3.88	Highly feasible
Graphical	3.63	Highly feasible
Average	3.70	Highly feasible

Discussion

The research undertaken was of a developmental nature, employing the 4D model. However, the dissemination stage was not executed due to the researchers' exclusive focus on the development and feasibility of the Agrophysics e-module. The initial phase of the project involved the establishment of a definition. The definition stage entailed a multifaceted analysis of needs, students, concepts, and competencies or tasks (Susilawati et al., 2023). At this stage, learning requirements were defined and formulated as the basis for developing the Agrophysics e-module.

The analysis conducted was to identify e-module requirements due to the limited availability of Agrophysics teaching materials and the fact that the majority did not focus in depth on physics in agriculture. Furthermore, there is a necessity for media that can be studied independently and media that suits the characteristics of students. This necessitates the creation of e-module that are easily accessible, interactive, and whose material links physics concepts with industrial agriculture. At this stage, the learning outcomes of the course and the learning objectives that support the University of Jember's vision and mission are also identified, equipping graduates with content that is characteristic of the Physics Education study programme. At this stage, the mapping of relevant physics concepts and the determination of materials were carried out. In conclusion, the final stage of the process was the definition stage, which entailed the analysis of tasks, the form of exercises, and their evaluation. For the exercises in this e-module, multiple-choice questions were employed, while for the evaluation, essay questions were selected.

The subsequent stage in the process is the design stage. The objective of this stage is to design or produce a product (Doyan et al., 2022; Fonna et al., 2022), which in this case is an Agrophysics e-module. The present stage of the project is concerned with the production of the design for the Agrophysics e-module. The stages in this process are as follows: firstly, the structure of the e-module is to be compiled; secondly, the storyboard is to be designed; thirdly, the media and format are to be selected; and finally, the instruments are to be designed. Following completion of the design stage, the subsequent stage in the process is the development stage.

The development of this Agrophysics e-module employs Articulate Storyline. This software is utilised in the development of interactive digital teaching materials (Afanin et al., 2025; Mumtahana et al., 2020). Despite its slide-based nature, it diverges from conventional presentation slides in that designers can create interactive slides equipped with branching layers, triggers and variables, thereby enabling users to learn in a personally adaptive manner. This software is capable of inserting images, audio, and even video, thereby increasing user interactivity (Donnellan, 2021). During the development stage, the material and media were validated, and user responses were collected during limited trials to determine the feasibility of the Agrophysics e-module.

Material validation is assessed based on content suitability, presentation suitability, and language suitability (Aulianingsih et al., 2021; Mutohoroh et al., 2022). The content suitability aspect received an average score of 3.68, indicating that the material was

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appropriate for the Graduate Learning Outcomes and Course Learning Outcomes, accurate, up-to-date, and able to stimulate students' curiosity. An example of the material in the e-module is that the application of various types of biochar to the soil will affect the soil's ability to retain water based on water content indicators. In addition, there is material related to the application of a mixture of biochar and compost fertilizer, with the results showing recommendations for the appropriate mixture to maintain soil quality so that it can support plant growth and development (Pramudita et al., 2025).

The validity of the material is also measured based on the aspect of presentation feasibility, which consists of indicators of systematic and logical presentation, clarity and coherence, visualization quality, and consistency and readability of the e-module. Based on these indicators, the average score for the aspect of presentation feasibility is 3.63, which is categorized as highly valid. Based on the results of each indicator, this e-module is clear and coherent in terms of material description, exercises, and evaluation with Course Learning Outcomes, as evidenced by a maximum score of 4. The design also supports readability and user comfort, obtaining a score of 4, although the quality of visualization only obtained a score of 3, which is the lowest score compared to other indicators. The low visual quality indicator suggests that improvements are needed regarding image or graphic resolution and layout (Ashel et al., 2025).

The final aspect in measuring the validity of the material is linguistic appropriateness. This aspect consists of indicators of grammatical and spelling accuracy, clarity of meaning and readability of sentences, consistency of scientific terms, suitability of language to the level of student ability, and integration of language with the scientific and academic cultural context. The results are clear: an average score of 3.6 for the language suitability aspect, with a category of highly valid. The language aspect is excellent and can be easily understood by students.

The material was validated using three aspects, and an average score of 3.63 was obtained for material validation, which is categorised as highly valid. Material experts confirm that the e-module is suitable for use, despite the need for improvements in sentence clarity. This result aligns with research (Daryanes et al., 2023) on media development using Articulate Storyline, which categorised material validity as highly valid due to the use of interactive Articulate Storyline media, making it interesting and easy to understand despite improvements needed in grammar.

Media validity is measured based on four aspects, namely visual appearance and design, technical aspects, media integration with material, and appeal and creativity. The visual appearance and design aspect consists of three indicators, namely layout suitability, visual quality, and clarity of illustrations. Each consists of two statements. The layout suitability indicator received a score of 3, which means it is feasible, the visual quality indicator received a score of 3.5, which means it is highly feasible, and the clarity of illustrations and graphics received a score of 3. From the indicator scores, the visual appearance and design aspect received a score of 3.17, which means it is feasible.

The technical aspect was assessed based on the indicators of ease of use, readability, and stability of format and functionality. The ease of use indicator scored 3.5, which means it is highly feasible, the technical feasibility indicator scored 3, and the stability of format and functionality indicator scored 4. Thus, the average technical aspect score was 3.5, which is highly feasible.

The aspect of media integration with material consists of indicators of media suitability with the characteristics of Agrophysics material, media suitability with Course Learning Objectives (CLOs), and consistency of presentation style. The indicator of media

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suitability with the characteristics of Agrophysics material obtained a score of 3, which means it is feasible. The indicator of media suitability with learning objectives scored 3.5, which means it is highly feasible, and the indicator of consistency of presentation style scored 3, which means it is feasible. These results show that from the indicator scores, an average of 3.17 was obtained for the aspect of media integration with material, which is categorised as feasible.

The attractiveness and creativity aspect consists of indicators of visual presentation creativity and the ability to attract interest in learning. The score obtained for the visual presentation creativity indicator is 4, and the indicator of the ability to attract interest in learning obtained a score of 3. Thus, the average for the attractiveness and creativity aspect is 3.5, which is categorised as highly feasible.

Based on these four aspects, media validation obtained a score of 3.34, which is categorised as highly valid. These results indicate that the Agrophysics e-module media designed using Articulate Storyline is feasible and visually and functionally suitable for implementation. These results indicate that this study is in line with other studies that the use of digital-based e-modules is a form of digital technology integration in education that has the potential to improve accessibility, engagement, and personalization in learning (Zou et al., 2023). It is also in line with Daryanes (2023) study, which had a media validation score of 3.69, categorized as highly valid. Interactive designs can be developed simply with consistent colors, illustrations to help students understand the content, and font sizes and backgrounds that are not distracting (Daryanes et al., 2023). E-modules using Articulate Storyline software can be developed as interactive media. Media designed with Articulate Storyline is easy to use because it can be accessed with a smartphone (Husna et al., 2022). The findings of this study also support that the 4D model is effective in producing valid and practical digital teaching materials. This study also contributes to the advantages of existing e-modules. The advantages are the integration of physics concepts with applications in agriculture.

The validation results clearly show that the material and media are highly feasible. The next step was to conduct a limited trial to determine the feasibility of the e-module from the user's perspective. The students' responses were crucial in gauging their learning experiences with the e-module and confirming its alignment with their learning needs (Nurwina et al., 2025). This trial was conducted with students majoring in Physics Education as the subjects. We measured user response using four aspects: content, language, utilisation, and graphics. The content aspect scored 3.70, the language aspect scored 3.59, the utilisation aspect scored 3.88, and the graphics aspect scored 3.60. The results are clear: the average user response was 3.70, categorised as highly feasible.

The utilisation aspect was awarded the highest possible score in comparison to the other aspects. This finding suggests that the e-module is technically straightforward to use, as it can be accessed via each student's smartphone, enabling them to study at any time and in any location (Darmaji et al., 2019). The adventages of smartphones has precipitated a paradigm shift in the realm of education, concomitant with enhanced accessibility and the quality of learning (Jr et al., 2021; Sisouvong & Pasanchay, 2024). The utilisation of smartphones in an interactive capacity has the potential to facilitate a flexible and efficient learning process (Husnita et al., 2023). In the context of this study, the selection of digital or e-module formative materials, accessible via smartphones, facilitates effective and efficient learning, thereby enabling students to study agrophysics material flexibly. Furthermore, the content aspect received a score of 3.70 (the second highest), indicating that the material is appropriate, informative, applicable, and discusses applied physics phenomena in agriculture.

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The features available in the e-module enable students to gain interactive learning experiences. For instance, in the exercise section, the application will respond to the students' answers in a manner that will motivate them to learn. This assertion is further substantiated by the commendable graphics, which garnered a commendable score of 3.63. Despite the substandard language score, it is nevertheless regarded as being highly feasible.

The Agrophysics e-module, which has been validated and undergone limited trials, has proven its suitability for implementation in learning. This Agrophysics e-module is a form of teaching material that supports sustainable industrial agriculture. Agrophysics is defined as the scientific discipline that applies the principles of physics to the field of agriculture. The e-module under discussion places emphasis on physical parameters that have the potential to be linked to the management of soil and crops. This e-module will definitely support student learning and have a long-term impact on sustainable industrial agriculture. This e-module is key to strengthening the profile of graduates of the Physics Education Study Program by equipping students with basic physics concepts and multidisciplinary applications in the field of agriculture. The interactive and digital features in the e-module will support the development of digital literacy and contextual problem-solving skills that will equip learners with the 21st-century competencies they need.

Conclusion

This study successfully developed an interactive Agrophysics e-module using the 4D model, specifically through the define, design, and develop stages. The validation results from material and media experts, along with positive user responses, confirm that the module is highly feasible and effective for undergraduate physics education. By utilizing Articulate Storyline, the e-module bridges the gap between theoretical physics and its practical application in sustainable industrial agriculture, specifically in soil and crop management.

Recommendation

The principal limitation of this study is that the dissemination stage was not carried out. Consequently, in future research, the implementation and measurement of the cognitive domain and agricultural science literacy of students will be pursued. Furthermore, the integration of additional educational resources, such as simulations or visualizations in three dimensions, is recommended to further enhance the learning experience of students.

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