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Development of a basic physics practical guide with PhET interactive simulation on the topic of kinematics and dynamics

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Abstract

Due to the lack of practical tools for supporting Basic Physics lecture activities, lecturers have turned to PhET Interactive Simulations. However, there is currently no guide to help lecturers and students conduct practical activities using these simulations. This research aimed to develop a guidebook for Basic Physics practicum activities utilizing PhET, evaluated by experts and small-scale users for feasibility. The research followed Borg and Gall's R&D model, consisting of: (1) data collection, (2) planning, (3) product development, (4) product validation, (5) product revision, and (6) product trials. Data were gathered through observation, interviews, and questionnaires. Product validation was carried out by three experts—one each in material, media, and language. A small-scale product trial involved five randomly-selected students from the 2024/2025 Academic Year. Validation and trial data were analyzed by comparing scores to the maximum possible per question. The resulting product was a basic physics practicum guide using PhET for kinematics and dynamics. Expert validation indicated: (1) very worthy (3.88) by the material expert; (2) worthy (3.12) by the media expert; and (3) very worthy (3.80) by the language expert. The small-scale trial produced an average feasibility score of 3.33. Further research should include large-scale trials of the guide.

Keywords: practical guide; PhET interactive simulation; kinematics and dynamics; Borg and Gall development design.

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INTRODUCTION

The basic physics course in the Computer Systems study program has a total of 3 credits. These 3 credits are divided into 2 credits of theory and 1 credit of practicum. The basic physics practicum lectures follow the contract and semester lecture plan. They cover the topics of kinematics and dynamics. Kinematics is a branch of physics that studies the motion of particles or objects but does not discuss the causes of this motion. Dynamics is a branch of physics that studies the motion of an object as well as the things that cause it to move. Students must carry out five practicum activities: (1) vectors; (2) straight motion; (3) parabolic motion; (4) force and displacement; and (5) momentum and impulse. The practicum

lecture activities are conducted in groups, and students are required to collect a practicum report independently. Results from interviews and observations with lecturers and students in the Computer Systems study program indicate that no laboratory or practicum equipment to support these activities. Previous practical activities used a few tools that the lecturer provided independently. This approach was not optimal. Only one tool was available for each activity, so students had to take turns. Some practical topics were not aligned with kinematics and dynamics. For example, the calorimeter practical for calculating the specific heat of materials, was included only because the lecturer owned the tool. This situation happened due to limited equipment, so practicals continued using whatever was available.

Current technological advances allow students to carry out practical activities without using real tools. Virtual labs make this possible. One virtual lab for basic physics practical activities is the PhET Interactive Simulation. It is available at https://phet.colorado.edu/. PhET stands for Physics Education and Technology, and it was developed by the University of Colorado. Students can use the PhET simulation through applications and websites. It contains many simulations, especially for mathematics and natural sciences (Perkins et al., 2006). Many studies have shown the benefits of PhET in learning. First, PhET has proved effective in online learning for electrical measuring instruments (Sidik et al., 2020; Syamsudin et al., 2023). Second, PhET simulations help improve learning outcomes for electrical circuits (Kurniawan et al., 2024). Third, PhET simulations improve students' practical skills in the conservation of mechanical energy (Rasyidi et al., 2024). Fourth, PhET simulations can increase students' interest and mastery of quantum physics concepts (Saregar, 2016). Fifth, using PhET simulations in basic physics practicums improves students' cognitive and psychomotor abilities (Muflihah et al., 2023). These benefits show that using PhET simulations in basic physics practicums is appropriate. They can help maximize activities. Previous research with Computer Systems students in basic physics courses shows that students' cognitive abilities at the C4 (analysis) level and their understanding of concepts, especially drawing conclusions, are still lacking (Puspitasari & Febrinita, 2019, 2020). Another issue that arises with the implementation of PhET in practical classes is that students lack knowledge of how to use it. This is because they have never used PhET in practical activities. Therefore, to facilitate the implementation of Basic Physics practicals using PhET Interactive Simulation, a practical guide is needed.

A practicum guide is a material that contains how to carry out practicum activities in a course and will be able to assist students in their implementation. In addition, previous studies have shown that the use of guides in practicum activities provides several benefits. First, practicum guides have been proven to improve practical skills in practicum lectures (Zakiya & Falamy, 2024). Second, the application of practicum guides improves students' scientific work abilities (Widyaningrum & Wijayanti, 2019). Third, students' critical thinking skills can improve after the implementation of practicum guides in lectures (Koiriah et al., 2022). Other studies have stated that students give a positive response to practicum guides used during lectures (Darmaji et al., 2019). The results of these studies indicate that the presence of practicum guides has a positive impact on student abilities and the quality of lectures. In addition, the results of previous research conducted on students of the Computer Systems study program showed that students' critical thinking skills were still low (Puspitasari et al., 2023). Based on this, because in the Computer Systems study program, especially the basic physics course, there is no guide for practicums, the research on developing this practicum guide will complement the practicum activities for the basic physics course in the Computer Systems study program.

The importance of developing a practical guide using PhET Interactive Simulation is also supported by the results of previous studies. The first study was the development of a practical guide using a PhET virtual laboratory on acid-base materials. The results of this study provided a highly valid and practical

guide, based on the input of material experts, media experts, and practitioners, with a score of over 85%. In addition, the practical guide also received a very interesting category in user testing with a score of more than 81% (Kholilah & Susainti, 2023). The second study was the development of a virtual PhET Simulation practical e-module on dynamic electricity. The results showed that the e-module was categorized as 'very good' and was suitable for use in learning, with a total average score of 90% (Octafianus et al., 2022). The third study was the development of a PhET Simulation-assisted learning module on Elasticity. The results of this study were a learning module that received a good category from material and media experts, with scores of 4.03 and 4.18, respectively. Furthermore, teacher and student questionnaires indicated that PhET-assisted learning modules were highly acceptable for use as teaching materials (Rafika & Pasaribu, 2024). Three previous studies on the development of PhET-assisted modules or practical guides indicated the need for practical guides for practical activities in the Basic Physics course of the Computer Systems Study Program.

The developed practicum guide will contain the title, objectives, theoretical basis, tools and materials, steps for implementing the practicum, practicum data, and necessary analyses. The practicum guide is specifically for Computer Systems students. This practicum guide focuses on the topic of kinematics and dynamics in accordance with the CPMK of the Basic Physics course. The CPMK of this course includes: (1) determining the uncertainty of the measurement results independently and in groups; (2) calculating the magnitude of the resultant vector graphically and analytically independently; (3) calculating the magnitude of linear, parabolic, and circular motion independently; (4) analyzing the causes of a moving object using the concept of Newton's First, Second, and Third Laws independently and in groups; (5) applying the law of conservation of energy to determine the final velocity of an object moving in a conservative system independently; (6) determining the location of the center of gravity of several flat shapes independently; and (7) determining the pressure on moving and non-moving fluids independently.

The research problems are (1) the lack of Basic Physics practicum tools; (2) Computer Systems Study Program students have never known and used the PhET Interactive Simulation website; and (3) there is no guide for practicums with PhET Interactive Simulation. Based on the research problems and previous theoretical studies, it is necessary to develop a practicum guide with PhET that can be used for practicum activities in the Basic Physics Course. This practicum guide will be tested for feasibility with three experts and users on a small scale. The novelty of this is (1) a practicum guide with the help of PhET for basic physics courses that have never been developed before in the Computer Systems Study Program; and (2) the topic of kinematics and dynamics practicums. This guide is used in practicum activities for basic physics courses that use a virtual lab, namely PhET Interactive Simulation. The guide was created to help students in practical activities, whether in groups or independently. Another benefit expected from this guide is that students have a better understanding of the concepts in basic physics courses, especially the topics of kinematics and dynamics.

METHODS

Research on the development of a basic physics practicum guide using PhET Interactive Simulation on the topic of kinematics and dynamics was conducted using the Research and Development (R&D) method. The development research design used was the 10-stage Borg and Gall model. However, in this study, only six stages will be used to accommodate the research timeframe. Figure 1 below shows the six stages in this study (Kartika et al., 2019).

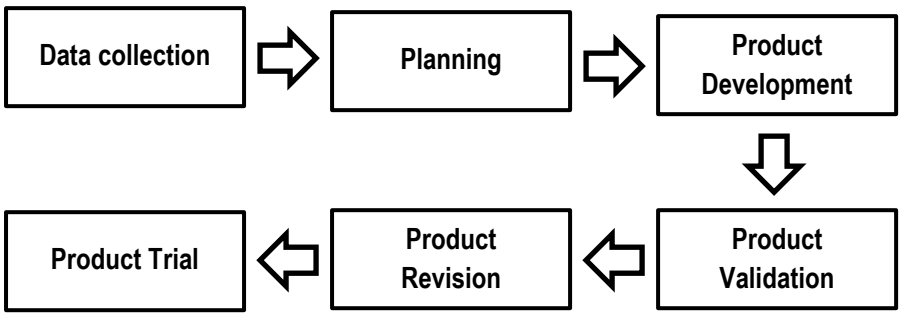


Figure 1. Six Stages of Borg and Gall's Development Research

The first stage is data collection using interview and observation techniques. Interviews were conducted with lecturers teaching the Basic Physics course and students of the Computer Systems Study Program who have taken the Basic Physics course. The purpose of the interviews was to obtain problems faced by lecturers and students in the practicum activities of the Basic Physics lectures. Interviews were also used to collect data related to initial knowledge about PhET. The interview technique in this study was an unstructured interview. Interview data was obtained through open-ended questions, so there was no interview guide. Meanwhile, observations were conducted during the implementation of basic physics practicum lectures. The purpose of interviews and observations was to collect information related to problems that exist in the implementation of basic physics practicums in the Computer Systems study program. Data mining through observation using unstructured techniques is carried out by recording all information during observations when students carry out practicums. After that, a literature review was conducted to determine solutions to the problems that had been found. The second stage was planning for the practicum guide to be developed. At this stage, the content components of the guide and the practicum topics were determined according to the Basic Physics CPMK. The third stage was the development of the basic physics practicum guide according to the predetermined components and topics. The fourth stage is product validation, conducted with material, media, and language experts. At this stage, the practical guide is provided directly to the validators, and then an assessment is conducted by completing a questionnaire. Table 1 below shows the assessment indicators in the questionnaire for each expert.

Table 1. Assessment Indicators for Material, Media, and Language Experts

Expert Validator		Assessment Indicators
Material	1.	The lab module aligns with the Basic Physics Course's Core Competency Standards (CPMK).
	2.	The virtual lab link listed in the module aligns with the lab to be conducted.
	3.	The lab module title aligns with the lab objectives.
	4.	The theoretical basis in the lab module can assist students in learning the material.
	5.	The lab module is equipped with work procedures that use imperative verbs.
	6.	The work procedures in the lab module are presented coherently and systematically.
	7.	The lab results data table aligns with the lab objectives.
	8.	The questions in the data analysis points align with the lab objectives.
Media	1.	The lab guide conforms to ISO standards, A4 size (210 mm x 297 mm).
	2.	The font type (typeface and numbers) in the lab guide is appropriate.
	3.	The font size (size of letters and numbers) in the lab guide is appropriate.

Expert Validator	Assessment Indicators
	4. The lab guide cover design is attractive. 5. The lab guide title is highlighted more prominently than the cover background color. 6. The composition of layout elements (title, author's name, the design (identity of the study program and university, as well as illustrations) is balanced and has a pattern that matches the layout of the contents of the practicum guide. 7. The front cover layout (text and image layout) in the practicum guide is proportional. 8. The practicum guide is equipped with appropriate images.
Language	1. The sentences used in the practicum guide are clear. 2. The sentences used in the practicum guide comply with good and correct Indonesian language rules. 3. The sentences used in the practicum guide do not contain elements of ethnicity, religion, race, and intergroup relations (SARA). 4. The language used in the practicum guide is effective and efficient. 5. The practicum guide uses language that is easy to understand.

The fifth stage is product revision based on the validation results from material, media, and language experts. The final stage is a small-scale product trial. The research subjects were 26 Computer Systems students who had taken the Basic Physics course. However, in the small-scale trial, 5 (five) students were selected using a simple random sampling technique. The method used was to assign sequential numbers 1 to 26, then randomly select five students with the identities in Table 2 below.

Table 2. Student Identities in the Small-Scale Trial

Student	Student's Name	NIM
1	Anggara Putra	23104420025
2	Ega Sandya Adinata	24104420012
3	Ananda Citra Novia	24104420009
4	Muhamad Habib Satria Erangga	24104420003
5	Naufal Zidan Khansa Aqila	24104420008

The data collection process for the small-scale trial involved students conducting practical activities using the developed guide. Afterward, students were asked to complete a questionnaire with the indicators in Table 3 below.

Table 3. Product Trial Assessment Indicators

Number	Assessment Indicators
1	The practical guidebook is very interesting to read and has honed my skills
2	The illustrations in the practical guidebook motivate me to learn.
3	This practical guidebook made it easier for me to understand the material.
4	The illustrations in the guide made it easier for me to understand the lab activities.
5	The practical guide helped me learn physics.
6	The practical guidebook covered the material clearly and coherently, making it easy to understand.
7	The content in the practical guidebook is supplemented with illustrations relevant to the material.
8	I can use the practical guidebook repeatedly.
9	The practical guidebook broadens my knowledge of kinematics and dynamics.

Data collection at the product validation and product trial stages is carried out by providing an assessment sheet with a Likert scale, namely:

1 = not good/not appropriate
2 = not good/not suitable
3 = good/appropriate
4 = very good/very appropriate

The assessment score based on the expert validation results will be calculated using the equation below.

$$assessment\ score = \frac{(total\ score\ )}{(maximum\ score)} \times 4 \quad (1)$$

Based on these calculations, the items will be categorized into four categories, adapting the research entitled "Four Common Misuses of the Likert Scale" (Pornel & Saldaña, 2013). The following is the categorization used in developing the basic physics lab guide.

Table 4. Assessment Sheet Categories

Average Score	Category
3.50 – 4.00	Very Worthy
2.50 – 3.49	Worthy
1.50 – 2.49	Less than adequate
1.00 – 1.49	Unworthy

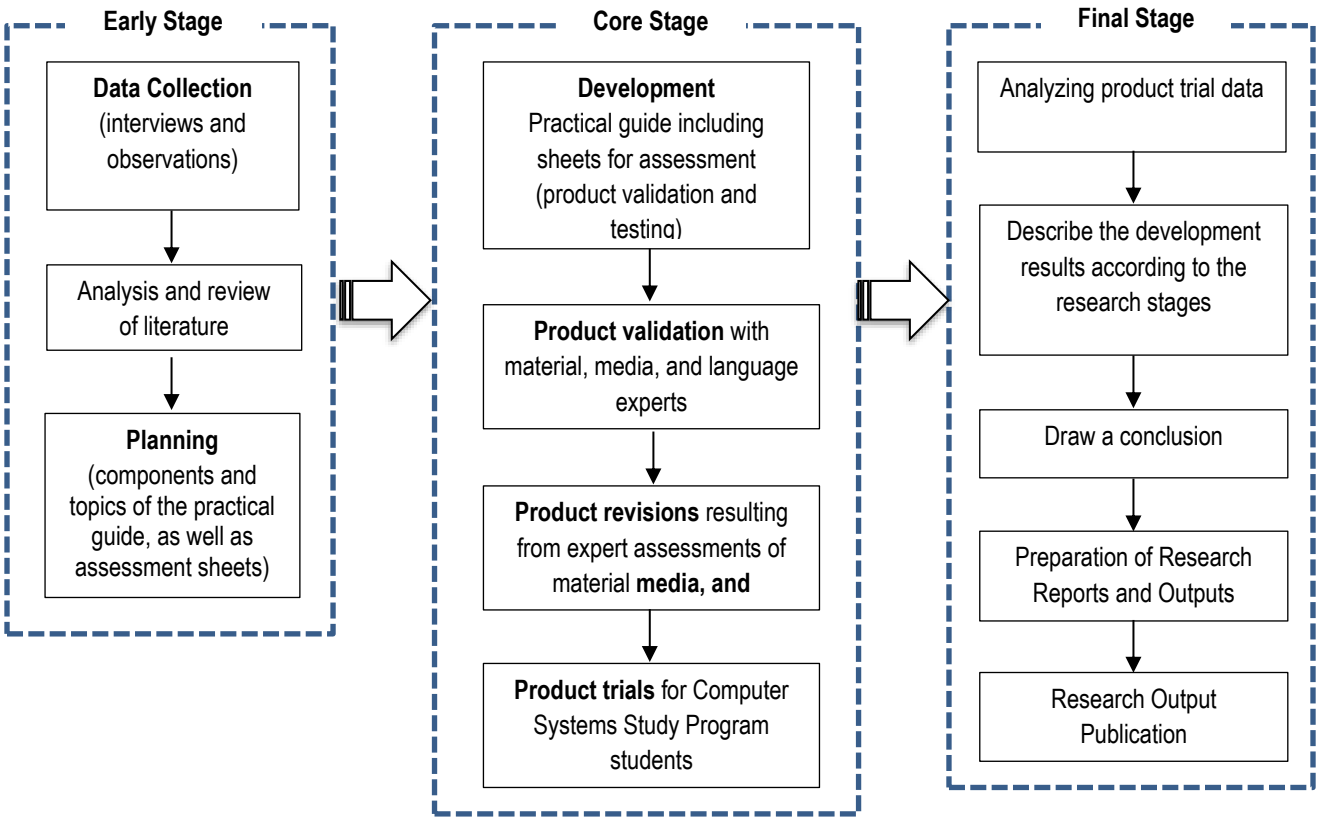


Figure 2. Research Stages for Developing a Basic Physics Practical Guide with PhET Interactive Simulation on the Topic of Kinematics and Dynamics.

Based on Table 4, the resulting product, namely the basic physics practical guide, is declared to have been successfully developed if the validation results achieve a minimum score of 2.50 or within a worthy range.

The stages of research and development of this basic physics practical guide are shown in more detail in Figure 2. Figure 2 above shows the stages of this research, which are grouped into three stages: initial, core, and final. The initial stage is the stage carried out to explore the research problem and gather information to produce a product that is appropriate to the problem at hand. The core stage is the stage of product development up to the product trial in small groups. At this stage, after the product has been developed, validation testing is first carried out by experts. The product that has gone through the expert revision stage will be tested on three (3) computer systems study program students who have taken basic physics courses. The final stage is the stage for analyzing the results of the product trial and summarizing all the results that have been obtained and describing them in a research article. In addition, conclusions are also drawn from the results of the research that has been carried out.

RESULTS AND DISCUSSION

The research on the development of a basic physics practicum guide was carried out using the Borg and Gall development design and consisted of 6 (six) stages, namely data collection, planning, product development, product validation, product revision, and product testing (Kartika et al., 2019). The results of the data collection stage were research problems, namely (1) the lack of practicum tools that support basic physics lectures, and (2) the absence of a practicum guide that supports the implementation of basic physics practicum lectures. The results of the planning stage were solutions to the research problems, namely (1) the implementation of a virtual laboratory with PhET Interactive Simulation as a substitute for the limited practicum tools and (2) the development of a practicum guide for a virtual laboratory in accordance with the CPMK of the Basic Physics course for the topic of kinematics and dynamics. After finding a solution to the research problem, the third research stage was carried out, namely development, and the results of this stage were a basic physics practicum guide book with PhET Interactive Simulation on the topic of kinematics and dynamics. In detail, the contents of this guidebook are the cover page, table of contents, chapter I: Introduction, chapter II: Writing Practical Reports, chapter III: Basic Physics Practical Instructions, bibliography, and appendices.

The next stage was product validation with three experts, namely media, materials, and language. The results from the three validators are shown in Table 5.

Table 5. Results of Expert Validation by Material, Media, and Language

Expert	Rating Scale				Total Score	Maximum Score	Assessment Score
	1	2	3	4			
Material	-	-	1	7	31	32	3.88
Media	-	-	7	1	25	32	3.12
Language	-	-	1	4	19	20	3.80
Average							**3.60**

Based on Table 5, the total score, maximum score, and assessment score were obtained. Calculating the assessment score using the equation resulted in a score of 3.88 for the material expert, 3.12 for the media expert, and 3.80 for the language expert 3,80. The average score for the three experts was 3.60. The results of the calculation of the assessment scores from these experts will be categorized according

to Table 4, and the results will be shown in Table 6.

Table 6. Results for the Categories of Material, Media, and Language Experts

Expert	Assessment Score	Categori
Material	3.88	Very Worthy
Media	3.12	Worthy
Language	3.80	Very Worthy
Average	**3.60**	**Very Worthy**

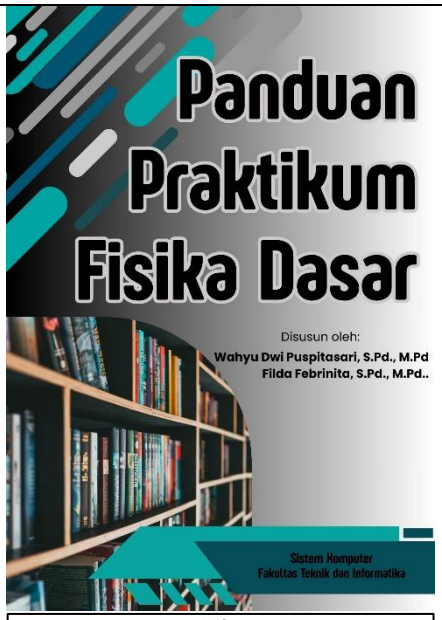
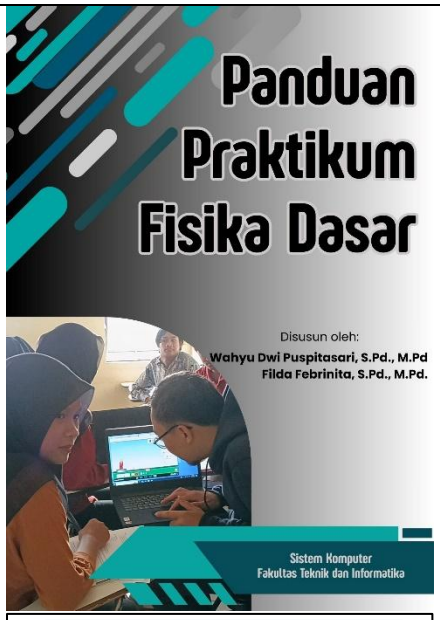
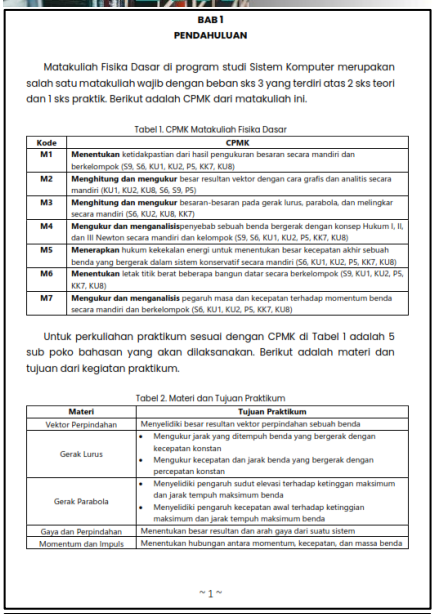
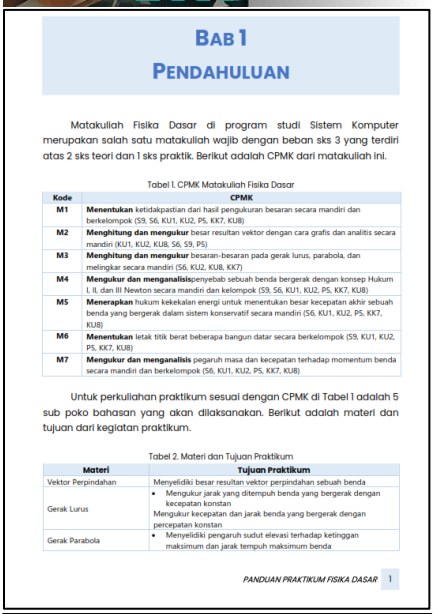
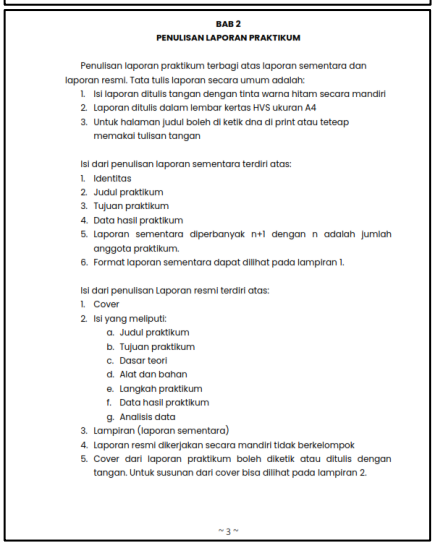
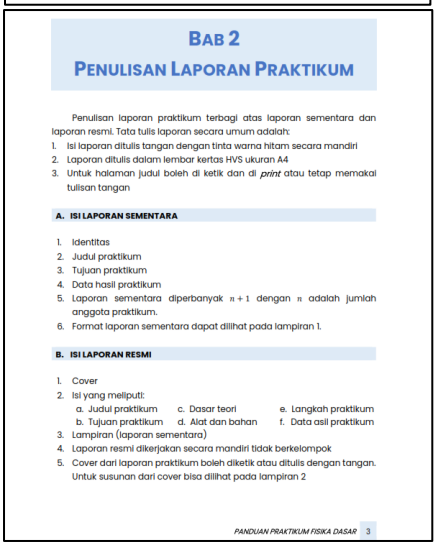
The results of each validator's decision, along with their suggestions for the basic physics lab guide using PhET interactive simulation on the topic of kinematics and dynamics, are shown in Table 7.

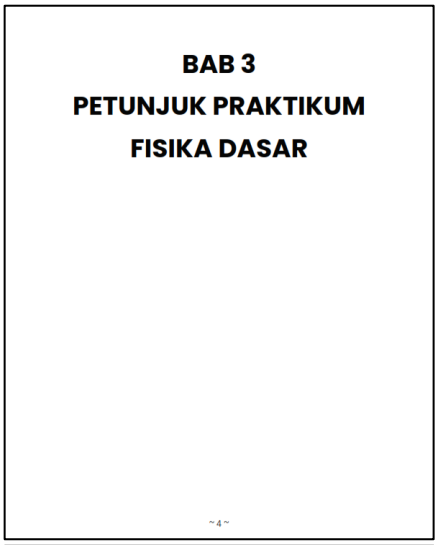
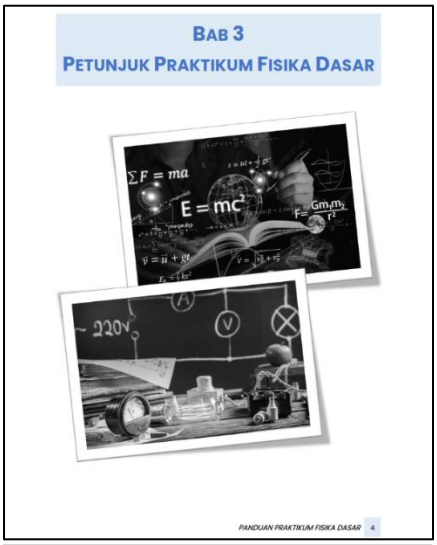
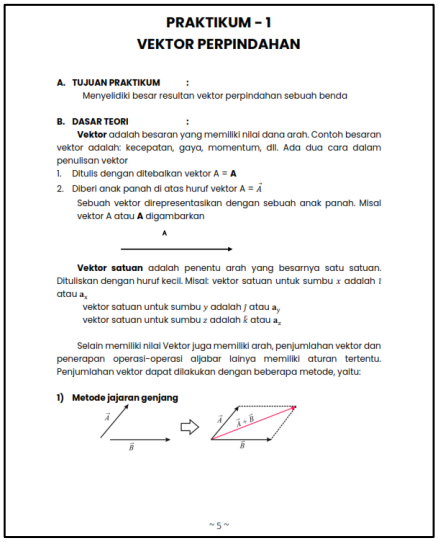
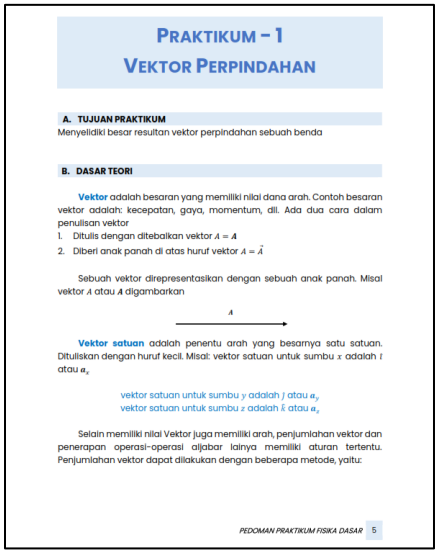
Table 7. Validation Decision Results and Suggestions from Material, Media, and Language Experts

Expert	Decision	Suggestion
Material	Suitable for use without revision	Basic Physics practical guide is suitable for use
Media	Suitable for use with revision	Some things that could be improved: 1. On the cover, it is best to include "Study Program", so that it is written: Computer Systems Study Program, Faculty of Engineering and Informatics 2. The author's writing on the cover is not proportional and there is excessive punctuation. 3. The image on the cover should match the title. For example, use an image of a practical activity, either in class or in a laboratory, to ensure the image and title are more in sync. 4. There is an inconsistency in the writing of letters as variables/units. 5. There are some margins and spaces that still need to be readjusted so that the appearance of each page is more proportional and consistent. 6. The chapter break page is not proportional in terms of layout, and it would be better to add a suitable image so that the appearance is more attractive and maximizes the space on one page.
Language	Suitable for use without revision	The practical guide is seen from the grammar that it is good and suitable for use.

The validation results shown in Table 7 above indicate that two experts, namely material and language, stated that the practicum guide was valid without revision. Meanwhile, based on the media expert, the practicum guide was declared valid with revision. The results of this expert validation served as a reference for the fifth stage of the research, namely product revision. Revisions prioritized the display design according to suggestions and input from media experts. A comparison of the practicum guide before and after revision is shown in Table 8.

Table 8. Comparison of Practical Guidelines Before and After Revision

Part	Before	After
Cover		
Chapter I Layout		
Layout Chapter II		

Part	Before	After
Layout Chapter III		
Practical Instructions Layout		

Based on Table 8, the first revision was made to the cover or cover page, namely by correcting the font size in the title, replacing the image, and changing the color of the study program and faculty writing from black to white. Next, changes were made to the overall layout by changing the color and highlighting the chapter titles and subtitles. In addition, an image was added to Chapter III. The results of the revision to the practicum guide were used in the product trial stage. The product trial stage was carried out with the assistance of 5 (five) computer systems study program students who had taken basic physics courses and had participated in practicums with PhET interactive simulation. Each student was given a practicum guide and then asked to fill out an assessment questionnaire. Table 9 below shows the results of the product trial for the 5 (five) students.

Table 9. Product Trial Results

Student	Rating Scale				Total Score	Maximum Score	Assessment Score
	1	2	3	4			
1	-	1	5	3	29	36	3.22
2	-	2	6	1	26	36	2.89

Student	Rating Scale				Total Score	Maximum Score	Assessment Score
	1	2	3	4			
3	-	-	1	8	35	36	3.89
4	-	-	7	2	29	36	3.22
5	-	-	5	4	31	36	3.44
Average							**3.33**

Table 9 shows the results of the questionnaire in the small-scale product trial. The completed assessment scale ranges from 2 to 4. The five students had different opinions regarding the practicum guide, as indicated by the varying assessment scores. The lowest assessment score obtained was 2.89, and the highest was 3.89. At the lowest score, the practicum guide received a score of 2 for two statements and a score of 4 for one statement. For the highest score, it received a score of 3 for one statement and a score of 4 for eight statements. After calculating the average assessment score of the five students, the product trial result was 3.33. Furthermore, the results of the assessment score calculation will be categorized using Table 4, and the results indicate that the lab guide falls into the "worthy" category.

This research has gone through all the planned stages of Borg and Gall to produce a product, namely a practical guide for a virtual lab that helps in the implementation of Basic Physics practical activities with PhET interactive Simulation, and has been declared worthwhile by experts and users. There are three experts who have assessed the guidebook, namely, material, media, and language experts. Based on Table 5, the assessment score of the material expert is 3.88, the media expert is 3.12, and the expert is 3.80. The conclusion for each expert, based on Table 4, is that two experts, namely material and language experts, stated that the practical guide is suitable for use without revision. While the media expert concluded that the practical guide is suitable for use with revision. Revisions that need to be made are the completeness of the identity, images, and typos on the cover. Another thing is the writing of the content and layout. The lowest score for the three experts was obtained from the media expert, and the average assessment score from the three experts was 3.60, with the assessment category being very worthy (Pornel & Saldaña, 2013).

The revised and valid practicum guide was given to users, namely, 5 (five) computer systems study program students. The average assessment score from the results of the product trial to users was 3.33 and was included in the high category (Pornel & Saldaña, 2013). Although it was categorized as "adequate," a deficiency was found, as seen in Table 5. Two students gave a score of 2 for the statement, "The lab guide made it easier for me to understand the material during the lab, the practicum guide guided me in learning basic physics, and the practicum guidebook has a clear and coherent coverage of material so it is easy to understand". Based on these results, it shows that users in this case are students who assess that the guideline is still not appropriate in making it easier to understand and guide in learning physics, and the material is not coherent and clear. These findings can be used as a reference for further research on the basic physics practicum guide, namely by revising the preparation of the theoretical basis that underlies each activity.

Furthermore, assessment scores of 3 and 4 were given for the questionnaire statement "the practicum guidebook is very interesting to read and is able to hone my skills. The pictures in the practicum guidebook motivate me to learn, the pictures in the guidebook make it easier for me to understand the implementation of practicum activities, the contents of the practicum guidebook are equipped with pictures that are appropriate to the material, the practicum guide can be used repeatedly, and the

practicum guide increases my insight into the material of kinematics and dynamics". These results indicate that students stated that the practicum guide is suitable for use in assisting practicum activities. In addition, students also assessed that the practicum guide can increase knowledge of the material of dynamics and kinematics. This result is an advantage of the basic physics practicum guide using PhET Interactive Simulation on the topic of kinematics and dynamics. This is because no student gave an assessment score of 1 on the questionnaire. Based on the results of this product trial, students assessed that the developed guide was helpful in carrying out practicum activities. The overall results of the research are also consistent with several previous studies listed in the background (Darmaji et al., 2019; Widyaningrum & Wijayanti, 2019; Zakiya & Falamy, 2024).

Based on previous research, the results can be used as a reference for developing guidelines for subsequent topics if further research has been conducted to revise them based on the results of small-scale product trials and large-scale product trials (Kholilah & Susainti, 2023; Octafianus et al., 2022; Rafika & Pasaribu, 2024). Furthermore, this practicum guide will be more effective if further development is carried out by presenting it in the form of an Android-based e-module. This is because e-modules have proven to be more practical and effective for independent learning and can improve physics skills (Fauziah et al., 2022; Yusuf et al., 2024).

CONCLUSION

The research has been successfully conducted and produced a Basic Physics practicum guide with PhET Interactive Simulation on the topic of kinematics and dynamics. This practicum guide has been declared worth by three experts, namely material experts 3.88, media experts 3.12, and language experts 3.80, and the average of the three is 3.60, which indicates the assessment category is very worth. Furthermore, based on small-scale product trials, the results obtained for this practicum guide are in accordance with the average assessment score of 3.33. Based on these two assessments, the developed practicum guide is worth pursuing and can be subjected to further research, namely, large-scale product testing. This aims to obtain a practicum guide that can be used as a reference in developing practicum guides for other topics. In addition, it can also improve the quality of the practicum guide so that it can be proven effective in helping students understand basic physics concepts.

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Declarations

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