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Instrument Development of Dynamical Modelling Skills in Computational Physics Course

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Abstract. This research aims to develop an instrument for assessing dynamical modelling skills, especially in the Computational Physics course. The instrument was developed using a 4D model (Define, Design, Develop, Disseminate). The proposed indicators consist of basic programming capabilities, visualization tools, modeling of physical phenomena, and execution. Each indicator is reduced to more detailed statement items. There are five experts who assess the relevance of items using Likert scale format indicators. The expert validation results were analyzed using the V-Aiken equation and a score of 0.88 was obtained so that the instrument developed was said to be valid and could be used to measure dynamic modeling capabilities.

Keywords: instrument development, dynamical modelling skills, computational physics course

1. Introduction

The development of technology is very beneficial in education where teaching in the classroom is greatly helped by the use of this technology. ICT provides new tools that can improve the learning and teaching process [1]. Some of the advantages of using IT in learning are that it can increase student engagement and knowledge retention, as well as encourage independent learning and student collaboration [2]. Apart from that, students can learn useful life skills through technology. Therefore, nowadays the use of computers has been widely integrated into the educational curriculum.

The implementation of the teaching and learning process in the laboratory can be improved by introducing more effective delivery techniques through the use of software. The use of computers in learning not only makes it easier to write long documents or calculations, but more than that, many programming languages have been developed that can be used to visualize physical phenomena. Nowadays the programming language that is widely used is Python. One of the uses of Python in learning was carried out by [3]. They invite students to learn the importance of virtual laboratories as a visualization element when discussing physics content in class. This visualization is one of the things that can be done in computational modeling.

Computational modeling (CM) is a core methodology of interdisciplinary science that enables the interweaving of data and theoretical perspectives from multiple domains to address complex problems [4]. CM allows us to analyze complex systems that require very sophisticated mathematics or that cannot be analyzed at all without computers [3]. CM is now as important as theory and experimentation in science [5]. VPython programming was chosen as one of the languages to introduce CM in the science curriculum which is based on new practical learning.

Learning computational physics introduces the use of programming languages to study physical phenomena. To measure student understanding, one technique that can be used is assessment in the form of a project. From the results of student projects, it can be easily seen the level of student understanding, starting from physics concepts to expressing them in visualizations using certain programming languages. This assignment in the form of a project is carried out in stages and continuously, starting with submitting a project title where students are asked to explain the physics concept first, followed by designing a visualization process to obtain system dynamics. Therefore, this project assignment can be used to measure dynamic modeling capabilities.

Students' ability to understand physical phenomena needs to be measured in order to know the level of learning success. For this reason, we need a measuring instrument that can be used validly. This tool is an assessment instrument. As has been done by [6] who developed an instrument to measure HOTS in Physics. Then, [7] also developed an instrument to measure the use of online comics as an educational medium and [8] who developed a numeracy skills test instrument. The existence of a valid instrument guarantees that the instrument can be used as a credible measuring tool.

This research aims to develop a dynamical modelling capability instrument. This instrument was developed specifically to measure students' ability to understand physical phenomena and realize them in visualization.

2. Method

2.1. *Development Model*

The research method used adopts the 4D development model [9], which consists of four stages ilustrated in Figure 1. The details of the development stages are explained as follows: (1) Define. This stage is related to development requirements carried out through needs analysis. Based on the literature review, the author has not found any assessment instruments used to measure dynamic modeling abilities in Computational Physics courses. Therefore, this dynamical modelling skills assessment instrument was prepared with the hope that it could become a prototype for further development. (2) Design. This stage is carried out by recording the indicators used to measure dynamical modelling skills. (3) Develop. This stage produces a development product in the form of a prototype of a dynamical modelling skills assessment instrument. (4) Disseminate. The dynamical modelling skills assessment instrument was reviewed by experts so that its level of validity could be obtained, then tested as a project assessment instrument in the Computational Physics course.

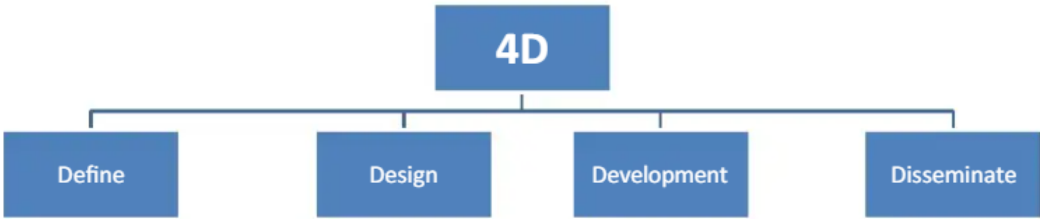

Figure 1. The 4D development model [9]

2.2. *Content Validity*

Content validity is determined based on expert agreement, which is also known as the measurable domain, determining the content stratification of content validity. This happens because measuring instruments, for example tests or questionnaires, are proven to be valid if experts are of the opinion that the instrument measures mastery of abilities determined in the domain or psychological construct being measured [10]. To understand this agreement, validity indices can be used, including the item validity index proposed by [11,13] as follows

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

where V is the item validity index, s is the score determined by each assessor minus the lowest score in the category used (s = r - lo, with r = score of the assessor's category selection and lo the lowest score in the assessment category), n is the number of assessors and c is the number of categories that the assessor can choose. If applied to measuring tools, according to the appraiser, n can be replaced with m (the number of items in a tool). The V index value ranges from 0 to 1. The closer an item is to 1, the better it is because the more relevant it is to the indicator.

3. Results and Discussion

The research results are explained in accordance with the sequence of development carried out.

3.1 *Define*

First step we are defining the model. The dynamical modelling designed in this development is reviewed by researchers continuously. The initial prototype developed in this research consists of four indicators, namely basic programming, visualization tools, modelling, and execution. These indicators are defined based on teaching experience with a series of activities in the Computational Physics learning process briefly explained as follows: (a) Introduction to basic programming. The introduction to basic programming was carried out by introducing Python using Google Colab. The first is an introduction to the Google Colab workspace, starting with opening it and then writing simple code. The second is an activity to introduce variables in Python, including text, numbers and sequences. Third, independent practice of activities that have been demonstrated on each device. Some questions from students that arise at this stage include the choice of using a cellphone or computer, identifying errors in variable selection, and coding restrictions. (b) Introduction to visualization tools. To create visualizations, several libraries/tools are needed. In the basic part, just be introduced to Numpy and Matplotlib. Numpy is related to operations between variables and sequences, while Matpotlib is related to graph creation, namely the introduction of functions, domains and ranges. Questions from students regarding identification of program errors. (c) Case study of physics phenomena modelling. To ensure students can understand physics concepts, modeling case studies are carried out in two steps, namely demonstration and exploration. A demonstration is given in the case of a harmonic oscillator, the physics concept is explained and then translated into a programming language. Then students are invited to explore further by finding out for themselves the principles of physics which are visualized based on the experience they have gained and reference books. The results of the exploration in the form of selected cases to be visualized are first consulted with the lecturer. This exploration is an individual task with different cases between one student and another. (d) Program execution. After the selected case is approved, the next step is for students to visualize the case.

3.2 *Design*

Second step is designing model. Based on the learning steps at the Define stage, items developed to be used as dynamical modelling indicators are proposed as follows. (a) Student abilities in basic programming. Students must master basic programming if they want to do dynamic modeling. Starting from students' understanding of the software work environment, types of variables, basic variable operations, and variable manipulation. (b) Student knowledge of visualization tools. Once students have confirmed their knowledge and understanding of the variables, visualization tools must also be known. This knowledge can be measured from students' ability to differentiate between independent variables and dependent variables, understanding advanced operations between variables, understanding domains and codomains, as well as the ability to use graphing tools. (c) Students' ability to choose to physical phenomena modelling. The next ability is being able to find the phenomenon to be modeled. Students are asked to search for and discover the phenomenon themselves, report it to the lecturer to get approval and guarantee that the selected phenomenon can be visualized. After the selected physical phenomenon is obtained, students must be able to name all the physical variables contained in the selected physical phenomenon, differentiate between constants and dynamic variables, state the applicable physical laws, find the form of the differential equation, and find the solution to the differential equation. (d) Students' ability to execute physical phenomena modelling. The execution referred to here is the process of creating the visualization which starts from determining parameters, initial domain values, writing solutions to differential equations, writing the visualization process into a programming language, and analyzing the visualization results.

3.3 *Develop*

Third step is developing instrument for Dynamical modeling. The following is a presentation of the results of the instrument development that has been carried out as shown in Table 1. We explained the dinamical modelling skills in four indicators with various statement. The total statement are 20 items.

Table 1. Indicators and statement items.

Indicator	Statement	Number
Basic Programming	Student understanding of the software work environment	1
	Student knowledge of types of variables	2
	Student abilities in basic variable operations	3
	Student abilities in variable manipulation	4
Visual Library Tool	Students' ability to differentiate independent variables and dependent variables	5
	Student understanding in advanced operations between independent and dependent variables	6
	Student understanding of variable domains	7
	Students' understanding of the codomains of independent and dependent variables	8
	Students' ability to use graphic creation tools	9
Modelling of physics phenomena	Students' ability to discover/create physical phenomena/modelling	10
	Student's ability to name all physical variables contained in selected physical phenomena	11
	Students' ability to differentiate constants and dynamic variables in selected physical phenomena	12
	Students' ability to state the laws of physics that apply to selected physical phenomena	13
	Students' ability to find forms of differential equations in selected physical phenomena	14
	Students' ability to find solutions to differential equations in selected physical phenomena	15
Excecution	Students' ability to determine parameters	16
	Students' ability to determine initial domain values	17
	Students' ability to write solutions to differential equations	18
	Students' abilities in visualization	19
	Students' ability to analyze visualization results	20

3.4 *Diseminate*

Fourth step is disseminating the product as expert validation. This stage involved 5 validators who came from Physics lecturers. Expert review validates each statement on the dynamic modeling assessment instrument which is prepared based on the characteristics of content assessment, problem construction assessment and language assessment. The aspect has been reviewed shown in Table 2**.**

Table 2. Expert review aspect.

No	Rated Aspect
1	The criteria to be assessed are clearly stated.
2	The statement uses language that conforms to standard Indonesian language rules
3	Use communicative sentences/statements
4	Use simple and easy to understand language
5	The categories of aspects to be assessed are clearly stated
6	The aspect categories to be assessed are contained in full
7	The project assessment rubric is clearly stated

The assessments reviewed by experts are based on Likert scale criteria, namely 5 for very relevant, 4 for relevant, 3 for quite relevant, 2 for less relevant, and 1 for very less relevant. The expert validation results are presented in Table 3.

Table 3. Expert validation results.

Rated aspect	Score					V score
	Rater1	Rater2	Rater3	Rater4	Rater5	
The criteria to be assessed are clearly stated.	5	4	3	5	4	0.80
The statement uses language that conforms to standard Indonesian language rules	4	4	5	5	5	0.90
Use communicative sentences/statements	5	4	5	4	5	0.90
Use simple and easy to understand language	4	5	5	4	5	0.90
The categories of aspects to be assessed are clearly stated	5	4	3	5	5	0.85
The aspect categories to be assessed are contained in full	4	5	3	5	5	0.85
The project assessment rubric is clearly stated	5	4	5	5	5	0.95
Average						0.88

Based on the results of data analysis in Table 3, it can be seen that the average V-Aikens value of content validity by experts obtained an average score of 0.88. If this value is compared with the table value for five raters that is 0.80, we obtain $V_{count} \geq \mathrm{V}_{table}$ so that it can be concluded that the assessment instrument is said to be valid. This shows that the research results can be used as an instrument for assessing dynamic modeling abilities. As a test material, the assessment instrument is applied to Computational Physics learning. The test results are presented in Table 4 and it can be seen that the instrument can be used well because it is able to map students' ability levels in dynamic modeling in the Computational Physics course.

Table 4. Results of trials using assessment instruments.

Ranges	Grades	Number of Students
86-100	A	6
81-85	AB	8
71-80	B	2

This research develops an instrument to measure dynamic modeling skills which are the main achievements in the Computational Physics course. The validity of the instrument developed was assessed using the V-Aiken formula involving 5 raters. Different from what was done by [7] which uses item correlation value with the corrected item-total correlation to assess the validity of developing its instrument regarding the use of online comics as educational media. Likewise [8], the feasibility of the instrument being developed is only obtained from the average of the assessments of the three validators. As for [6] verified the validity and reliability of their instrument using content validity, classical test theory, and the Rasch model. The more complete the tests carried out, the more guaranteed the validity of the instrument being developed. Therefore, it is necessary to carry out further research to further examine the validity of the prototype instrument for assessing academic modeling skills.

4. Conclusion

A dynamical modelling skills assessment instrument has been developed with an average validation score of 0.88. This result means that the development product can be used as a prototype for a dynamic modeling capability assessment instrument.

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