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Development of Computational Physics Practical Instructions: Visualization of the Laplace Equation Phenomenon

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Abstract: Practical instructions for practical activities in computational physics courses have been successfully developed with material on the Laplace equation for temperature distribution. This research aims to produce practical instructions and determine the characteristics, feasibility, and responses of students to practical instructions for computational physics on the Laplace equation. The research design used is development research or R&D (Research and Development) which was modified from Sugiyono. The research was carried out at the Computer Laboratory of PGRI University Semarang with Physics Education study program students as research subjects. The research results show that the computational physics practicum instructions developed have the criteria "Very Feasible" based on validation from three computational physics experts with respective percentages of 96%, 99% and 93%. The characteristics of this computational physics practical guide are that it is prepared using computational thinking techniques, presented explicitly and equipped with algorithms, solving with two different scenarios (iterations and matrices) in one case as well as writing coding, uses the latest software (Python). This computational physics practical instruction received a very good response from students with a percentage of 87% in the initial trial and 88% in the usage trial.

Keywords: Physics education; Practical instructions; Computational physics

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Introduction

Adaptation to succeed in an ever-changing world is necessary. Not only adapting, being sensitive to change, being able to solve problems and developing tools to use and create technology are also very much needed in today's technological developments. Regardless of the field in which they want to work, students need to prepare themselves for the future with skills in communication, collaboration, creativity, critical thinking, and computing (Varela et al., 2019). Life in the education sector in the 4.0 era is the center of attention, especially the realization of intelligent education. Improving and equalizing the quality of education, expanding access and the relevance of the use of technology are the main focuses in realizing world-class smart education (Asiani, 2019).

Living in a digital ecosystem full of software-driven objects, of course the ability to handle computer languages emerges as an inevitable skill, a new literacy, which allows full and effective participation in the digital reality of "programming or being programmed" (Rushkoff, 2010 in Roman-Gonzales, (2017)). The term "code literacy" was created to refer to the process of teaching and learning to read and write using a computer programming language where someone is considered code literate if they are able to read and write in a computer language, as well as think computationally.

Responding to these challenges, according to PISA 2021, one of the recommended areas is computational thinking. The computational thinking taxonomy in PISA 2021 includes data practices, modeling and simulation practices, computational problemsolving practices, and systems thinking practices.

Computational physics or commonly called computational physics is a course that studies how to use computers to solve various physics problems numerically. Problem solving in computational physics courses is generally carried out with modeling and simulation practicums. Practical activities are a form of learning carried out in a certain place where students play an active role in solving given problems through the use of certain tools, materials and methods. In computational physics practicum, you can use several applications such as Matlab (Matrix Laboratory) and Python, where this application is software for technical and scientific computing that is able to integrate computing, visualization and programming (Asiani, 2019).

Practicums generally use practical instructions. Practicum instructions are practical implementation guidelines that contain procedures for preparation, implementation, data analysis and reporting to help the practicum process run smoothly. PGRI University Semarang has a Computational Physics course in the Physics Education Department, which is a course taken after taking the prerequisite course, namely the computer programming course. However, the problem at this university is that the practical instructions used are still included in the teaching materials and have not been explained clearly, especially in the Laplace Equation material. Based on observations and interviews conducted with several active students and lecturers of the UPGRIS Physics Education study program, the practical instructions used in computational physics courses are still included in the computational physics textbook and are still explained implicitly.

Laplace's equation is an equation that is widely used to model problems in the field of science. Laplace's equation is a type of partial differential equation. Because this equation has an important role in the modeling process, it requires instructions that explain the equation explicitly. The classic example of this equation is the elliptic equation. Laplace's equation is generally often found in heat transfer theory, elasticity, electrostatics, fluid mechanics, and other mechanics and physics problems.

Based on the explanation above, if we refer to the physics study program curriculum, it emphasizes three main competencies that students must have, one of which is computational skills, both Computational Thinking and program execution, hereinafter referred to as Computational Thinking (CT) and Programming Skills (PS). CT and PS are increasingly seen as skills that are important for creating rather than simply consuming technology (Resnick et al, 2009 in Roman-Gonzales, 2017). Its introduction to Computer Science and the non-major curriculum is considered essential. At the higher education level, research on the teaching of CT and PS as a set of basic skills is still lagging behind. Therefore, it is necessary to carry out research aimed at developing CT-based computational physics practicum instructions and analyzing the feasibility and students' responses to them.

Methods

The research method used is development research or R&D (Research and Development) modified from Sugiyono and a oneshot case study type experimental method to determine the effect of using practical instructions on the growth of computational thinking and programming skills, supported by appropriate literature studies.

Development research procedures include potential and problems, data collection, product design, design validation, design revision, initial trials, product revisions, use trials, product revisions (Sugiyono, 2020). This research stems from the problem of limited numbers and inappropriate computational physics practicum instructions used for practicum in computational physics courses with the demands and challenges of students having to have basic basic skills regarding the ability to demonstrate, program, and think computationally including data practice, modeling and simulation practice, computational problemsolving practice, and systems thinking practice. The data collection stage is carried out by collecting data/information needs related to the problems faced and developing practical instructions that are expected from computational physics courses, such as books, the internet and related articles. The prototype design for the computational physics practicum instructions that was developed has been designed in accordance with the requirements for completeness of the practicum instructions components and has gone through the validation stage by 3 validators, product revisions, initial trials on a sample of 15 physics students, and trial use on 40 students. The research was carried out at the Computer Laboratory of PGRI University Semarang with the research subjects being students of the Physics Education study program who had taken the prerequisite course Computer Programming, totaling 40 students.

Several data collection techniques used in this research include documentation, questionnaires and observation. The variables measured in this research were the feasibility of computational physics practical instructions and students' responses to computational physics practical instructions for visualizing the Laplace equation phenomenon. The feasibility of computational physics practicum instructions is measured based on the validation results of computational physics experts, namely lecturers in Computational Physics, Yogyakarta State University, UIN Walisongo Semarang and PGRI University Semarang through instruments in the form of questionnaires. Student responses were measured based on the results of a student response questionnaire to the computational physics practicum instructions that were developed. The data analysis technique used in this research is quantitative descriptive.

Results and Discussion

Computational Physics Practical Instruction Products

In this research, practical instructions for computational physics have been developed which include material on the Laplace equation. The computational physics practical instructions are made on A4 paper size (21 cm x 29.7 cm).

Figure 1. Cover of Practical Instructions

This practical instruction also has characteristics, including that it is prepared using computational thinking techniques which include decomposition, pattern recognition, algorithmic thinking, generalization and pattern abstraction. The second characteristic is that it is written using LaTeX software. The choice of writing using LaTeX software is because it has a structured, good and correct document format so that there is no confusion in writing. Apart from that, writing using LaTeX also minimizes errors in writing formulas and equations. There are also professional and attractive templates available. These practical instructions use the Overleaf version of the BioMed Central Article Template.

The third characteristic is that it is structured and presented explicitly, where the practicum instructions are presented clearly and without being complicated so that students can easily understand the meaning of the contents of the practicum instructions and do not have a vague or wrong idea about the contents of the practicum instructions. The fourth characteristic is the completion of two different scenarios in one solved case which is a characteristic of the practical instructions being developed. Two scenarios are used to solve the 1-dimensional Laplace equation, where scenario one uses an iteration and matrix scenario.

The fifth characteristic is writing the coding and visualization process of the Laplace Equation case, written in Python using the Python IDE, namely Spyder. The choice of the Python language in writing coding and the visualization process is because Python is the most updated and current programming language.

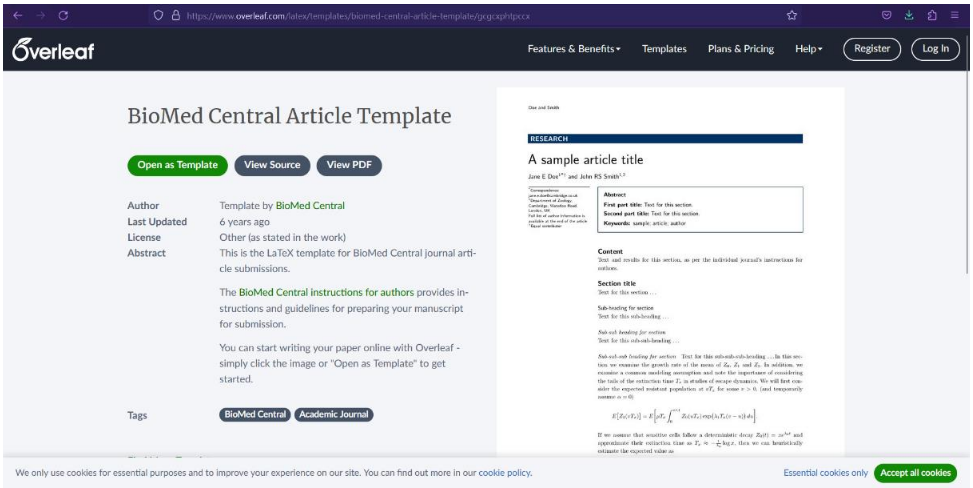

Figure 2. BioMed Template Overleaf

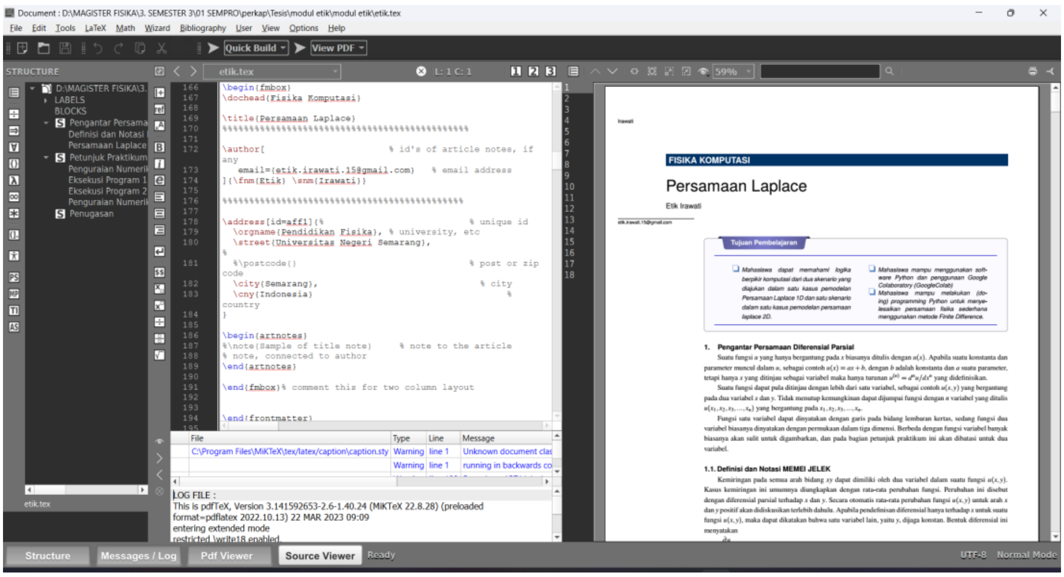

Figure 3. Display of Practical Instructions Title in LaTeX using BioMed Template Overleaf

In executing a program, it is of course very important to present the algorithm. An algorithm is a structured set of instructions, a step by step procedure in calculations. Algorithms are presented in each case solution which are then to be executed and/or visualized, this is the final criterion in the computational physics practical instructions that are developed.

Practical instructions for computational physics for visualization of the Laplace equation phenomenon in temperature distribution have a practical page consisting of the following parts: 1) practical title, 2) learning objectives, 3) literature review containing an introduction to partial differential equations, 4) instructions for implementing the practical, 5) assignments and 6) references.

The product, in the form of practical instructions for computational physics, visualization of the Laplace equation phenomenon, has gone through the feasibility assessment stage through validation by computational physicists. The results of the first stage of validation from the first, second and third validators, accompanied by suggestions and input, became the basis for revising the computational physics practical instructions, then tested in initial trials. The initial test results were then revised again and a second stage of validation was carried out by experts. The results of the second validation, accompanied by suggestions and input, are the basis for revising the computational physics practicum instructions which will later be tested in use trials. There were no revisions to the results of the usage trials, so no further revisions were carried out at this usage trial stage.

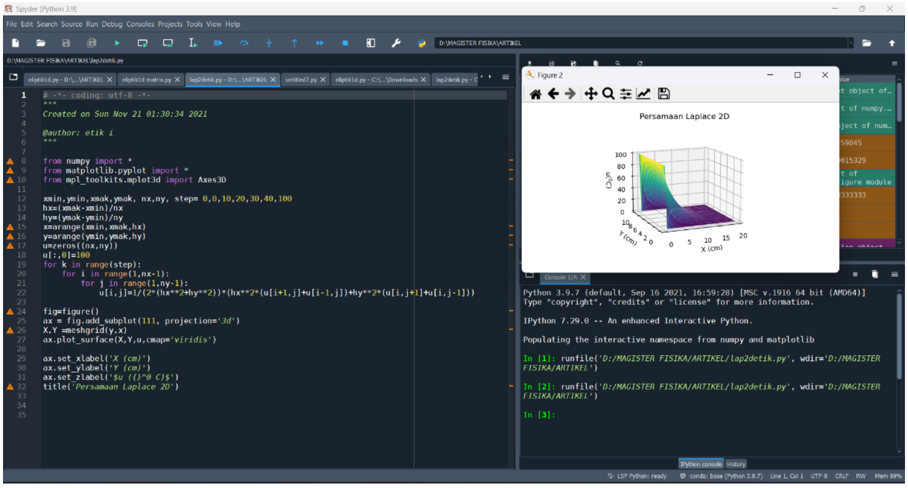

Figure 4. Software for Writing Coding Programs to Visualizing with Spyder

Validation of Feasibility of Computational Physics Practical Instructions

Validation of the feasibility of computational physics practical instructions for visualization of the Laplace equation phenomenon was carried out in order to obtain validation from computational physicists in developing these practical instructions. Apart from that, the aim of validating these practical instructions is to obtain constructive input so that the computational physics practical instructions that are developed can be better, along with a validation presentation by a computational physicist.

Table 1. Validation Results of Phase 1 Computational Physics Practical Instructions

No	Rated aspect	Validation Results		
		Validator 1	Validator 2	Validator 3
1	Eligibility of Content and Material			
2	Presentation Techniques			
3	Use of Language	85%	74%	93%
4	Compatibility of Computational Physics			
	Average Percentage	84% (Appropriate)		

Table 2. Validation Results of Phase 2 Computational Physics Practical Instructions

No	Rated aspect	Validation Results		
		Validator 1	Validator 2	Validator 3
1	Eligibility of Content and Material			
2	Presentation Techniques			
3	Use of Language	96%	100%	93%
4	Compatibility of Computational Physics			
	Average Percentage	96% (Very Feasible)		

The first stage of validation of the practical instructions by a computational physicist displays the results as shown in Table 1. Based on validation results by computational physics expert lecturers, an average presentation of 84% was obtained with appropriate criteria.

The second stage of validation of the practical instructions by a computational physicist displays the results as shown in Table 2. Based on validation results by computational physics expert lecturers, an average presentation of 96% was obtained with very feasible criteria.

Student Responses to Computational Physics Practical Instructions

Student responses to the computational physics practical instructions developed were determined through initial trials and usage tests. The initial trial was carried out on a sample of 15 people who were 5th semester students of the Physics Education study program at PGRI University Semarang. Meanwhile, the use trial was carried out on all students of the physics education study program at PGRI University Semarang who had taken computer programming courses, totaling 40 students. A recapitulation of students' responses to the computational physics practical instructions in the initial trial is shown in Table 3 and the usage trial is shown in Table 4.

Table 3. Student Responses to Computational Physics Practicum Instructions in the Initial Trial.

No	Rated aspect	Percentage	Criteria
1	Suitability of Content and Material	88%	Very Good
2	Usefulness	85%	Very Good
3	Presentation	88%	Very Good
	Average Percentage	87% (Very Good)	

Table 4. Student Responses to Computational Physics Practical Instructions in Use Trials.

No	Rated aspect	Percentage	Criteria
1	Suitability of Content and Material	89%	Very Good
2	Usefulness	87%	Very Good
3	Presentation	88%	Very Good
	Average Percentage	88% (Very Good)	

The results of student responses in the initial trial of the computational physics practical instructions showed a percentage of 87% with very good criteria. In the initial trial, there were revisions made, namely small revisions by adding reference sources and adding numbers to the equations

The results of student responses in trials using the computational physics practical instructions showed a percentage of 88% with very good criteria. Validation results and student responses in trials using physics practicum instructions in small-scale and large-scale trials show that the practicum instructions are very good for use in learning and practicum activities. The results of this research are in accordance with the research results of Toni Kus Indratno (2019) and the research results of Nindy Litia (2023) who developed a computational physics physics module for students majoring in education in the good category and suitable for use in computing physics lectures.

From a series of characteristics of the practicum instructions developed, it has been shown that the practicum instructions developed are different from existing practicum instructions. The differences between the practicum instructions that have been developed and those that already exist include: 1) The presentation of the previous practicum instructions is still implicit while the practicum instructions that have been developed are presented explicitly with evidence of per-sourcecode explanation in the listing. 2) Solving with two different scenarios in one case, in the previous practical instructions there was only one scenario for solving one case. 3) Completeness of algorithms, previous practical instructions did not contain algorithms in solving cases or in the program execution process.

Conclusion

Based on the research results, the following conclusions were obtained: (1) a computational physics practicum instruction product was produced for the practical activity of visualizing the Laplace equation phenomenon which has the characteristics of being prepared using computational thinking techniques and written using structured documents (LaTex), presented explicitly and equipped with algorithms, solving two different scenarios (iteration and matrix) in one case and writing coding using the latest software (Python) and equipped with algorithms. (2) the feasibility of computational physics practical instructions based on validation results by three computational physics experts with percentages of 96%, 99%, and 93%, respectively, with the criteria "Very Eligible." (3) the computational physics practical instructions received a very good response from students with a percentage of 87% in the initial trial and 88% in the usage trial.

With this practical instruction, it is hoped that it can provide an alternative or choice for lecturers to teach Laplace's Equation material in computational physics courses. These practical instructions can also add to the collection of practical manuals in the University physics laboratory.

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