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Train the computational thinking skill using problem-based learning worksheet for undergraduate physics student in computational physics courses

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Train the computational thinking skill using problem-based learning worksheet for undergraduate physics student in computational physics courses

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Abstract. Thinking steps of computational thinking skills have an essential role in forming creative thinking to find ideas in a structured manner. Not only developing creative thinking, but this stage also helps understand how to implement ideas into computational procedures. This study aims to design worksheets for helping the students understand and improve Computational Thinking Skill (CTS) in the material interpolation with the problem based learning (PBL) strategy. The development of worksheets using step: define, design, development, and disseminate. The development stage includes the evaluation from learning expert. In many studies, the application of PBL shows an increase in various student abilities. This research applied to 39 students of computational physics courses. The result shows there was an increase in CTS, such as abstraction from the complex problem, algorithm automation, data analysis, collection, and representation.

1. Introduction

Computational thinking skill (CTS) is one of the research topics that develop widely in various fields. Its implementation highlighted in the form of direct integration in the fields of natural and social sciences [1]. CTS is a fundamental concept in resolving various complex-real problems because computational thinking (CT) plays a role as well as an approach and problem-solving tools [2]. Higher-education providers must consider this as a challenge as well as an opportunity. Universities must integrate CT material to improve CTS for their students.It's through a link for each course as one of the problem-solving tools or into a special subject.

Increasing CTS is essential because it forms the skills needed in the 21st century. Development of CTS and digital literacy can be an approach to improve creativity, critical thinking, and problem-solving skills [3]. These skills combined with algorithmic thinking as part of CTS can improve many components of academic achievement [4].In mathematics and science, CT taxonomy is categorized into four majors, including data practices, modeling & simulation practices, computational problem-solving practices, and systems thinking practices [5].These various skills are certainly very well trained for students in science, engineering, and pre-service science teacher.

The CTS improvements are directed based on the types of CT stages. The CTS development through the specific material in modeling and simulation [6].This approach is effective for pre-service and in-service teachers because the material is directly linked to the teaching materials in schools. The CTS improvement through efforts to customize the learning environment. This

customization can be in the form of regularly providing online teaching materials [7], a visual programming environment [8], or a combination of environmental and pedagogical methods such as robotic programming with a multi-representation approach [9].Joyful learning strategies are also an option in applying CTS at various levels of education, such as puzzle [10] and game-based learning [11-13].Thematic approaches become a strategy for combining real problems with CTS for undergraduate students [14].

Many studies use specific pedagogical approaches to package learning aimed at enhancing CTS. Each learning strategy is dependent on the CT stages to be achieved. Some learning designs that are widely used are project-based, problem-based, teamwork, and game-based learning [15].These four designs have the same syntax; availabilities of problems and students are directed to solve the problem in accordance with the stages of CTS.

Problem-based learning (PBL) is one of the strategies widely used in CT activity because it has the characteristics to bring various authentic problems into the class. PBL conditions various information and relevant problems in a unit that is well illustrated [16]. This is what makes PBL an option for use in primary adult learning, such as undergraduate students. The syntax of PBL is as follows: read the problem statement; addressing questions and variables; design a plan for solving a problem; construct the model; test the model; make some recommendations and reflect the problem-solving process [17]. The steps are engaged to the CT well.

Furthermore, to facilitate the PBL approach in improving CT for undergraduate students, the lecturer must design worksheets that support the learning indicator requirements. In this paper, we explain how to develop a worksheet that aims to improve some CT skills with the PBL approach. The material is limited to interpolation material.This consideration is because the interpolation material is assessed to be able to bring up many thinking steps according to breaking down by previous research [18]. This study produces a worksheet with PBL characteristics and CT stages that are specifically used as objectives. It has modified the previous worksheet whose delivery model was limited to practical instructions.

2. Methods
The development of this work sheet use steps from the Thiagarajan 4D model [19], consist of: define, design, development, and disseminate. This stage is simple for the development of teaching materials. At the define stage, ananalysis of the material is carried out; this stage produces interpolation as material for the work shop to be developed. Next is to determine the CT stages for content in the interpolation worksheet. Next, is designing: the form and content of the work sheet, the design of learning, tests, and evaluations. The work sheet contains simulations and related questions that become PBL characters. The develop phase consists of a draft test of worksheets developed for colleagues. This stage of development is a cycle, repeated revisions. The last is the disseminate stage, which is done by testing it in lectures on undergraduate physics students.

3. Result and Discussion
One of the basic competencies in the Physics Computing course at the Physics Education Department UNJ is "students can apply linear and polynomial interpolation methods to data analysis issues." The topics discussed in interpolation are a linear interpolation, Lagrange's interpolation, and polynomial interpolation of measurement data. From the existing syllabus, it reveals that the measurement data fitting uses polynomial interpolation. However, not all data can be interpolated with polynomials. Therefore, the authors analyze that other interpolation methods are needed as additional material to supplement the basic competencies of students on the topic of interpolation.The material taught in the Cubic Spline Interpolation discussion is following the Numerical Analysis textbook [20], as shown in Table 1.

Table 1. Material Outline

No	Material
1	*Piecewise-Polynomial Approximation*
2	*Cubic Splines*
3	*Natural Cubic Splines*
4	*Clamped Cubic Splines*

From the results of curriculum analysis and material analysis, the instructional objectives can be formulated as follows: Students are able to apply the cubic spline interpolation method for simulation of data analysis problems. Students should explain why in a specific case, the polynomial interpolation cannot be applied in.

If f defined with $a = x_0 < x_1 < ... < x_n = b$, so f has S unique natural splineinterpolantat the points of $x_0, x_1, ..., x_n$; the points thatfulfill the requirement of $S''(a) = 0$ and $S''(b) = 0$. These requirements cause $c_n = S''(x_n)/2 = 0$ and $0 = S''(x_0) = 2c_0 + 6d_0(x_0 - x_0)$, so $c_0 = 0$. And form the equation $A\mathbf{x} = \mathbf{b}$, which A isthe matrix $(n+1) \times (n+1)$:

$$A = \begin{bmatrix} 1 & 0 & 0 & \cdots & \cdots & 0 \\ h_0 & 2(h_0 + h_1) & h_1 & \ddots & & \vdots \\ 0 & h_1 & 2(h_1 + h_2) & h_2 & \ddots & \vdots \\ \ddots & & \ddots & \ddots & \ddots & 0 \\ & & \ddots & h_{n-2} & 2(h_{n-2} + h_{n-1}) & h_{n-1} \\ 0 & & 0 & 0 & 1 \end{bmatrix},$$

whichb andxare vectors;

$$\mathbf{b} = \begin{bmatrix} 0 \\ \frac{3}{h_1}(a_2 - a_1) - \frac{3}{h_0}(a_1 - a_0) \\ \vdots \\ \frac{3}{h_{n-1}}(a_n - a_{n-1}) - \frac{3}{h_{n-2}}(a_{n-1} - a_{n-2}) \\ 0 \end{bmatrix} \text{ dan } \mathbf{x} = \begin{bmatrix} c_0 \\ c_1 \\ \vdots \\ c_n \end{bmatrix}.$$

Students should write the algorithm, following the equation above. The algorithm is then incorporated into the issue of outside image interpolation as in the [20].

3.1 Simulation1

The first step is to place the duck profile in coordinates to take several data points as shown in Figure 1 and Figure 2. The data points obtained are then arranged in tables to be plotted into the program.The coordinates data are presented in Table 2.
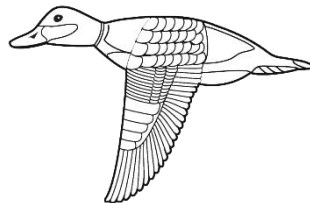

Figure 1. Profile Pictures of Ducks to be interpolated according to Examples in Burden & Faires[20]
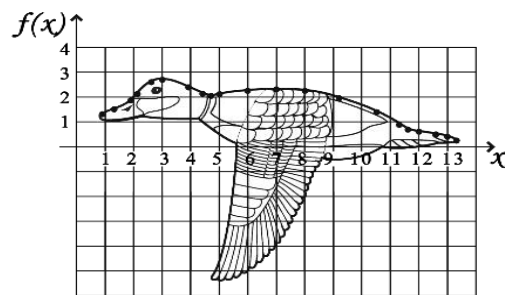
Figure 2. Profile picture of a duck placed in coordinates.

Table 2. The dots data

x[] =	{0.9,1.3,1.9,2.1,2.6,3.0,3.9,4.4,4.7,5.0,6.0,7.0,8.0,9.2,10.5,11.3,11.6,12.0,12.6,13.0,13.3};
y[] =	{1.3,1.5,1.85,2.1,2.6,2.7,2.4,2.15,2.05,2.1,2.25,2.3,2.25,1.95,1.4,0.9,0.7,0.6,0.5,0.4,0.25};

3.2 Simulation2

Simulation 2 used profile images of dogs. The steps are the same as Simulation-1. The dog profile images were provided in Figure 3 and Figure 4.

Figure 3. Dog profile Image that will be interpolated according to the Questions [20].
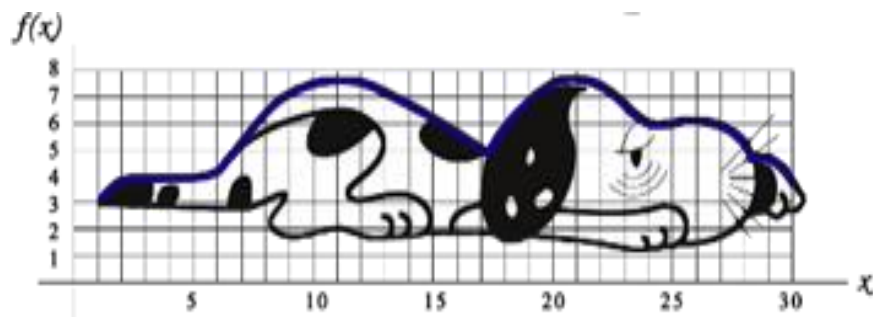

Figure 4. Dog profile images placed into coordinates and the results of running programs to interpolate the outline of the image [20].

3.2.1. Profile Image. The issue of image profile has the same completion steps as the simulation example made, as shown in Figure 5. It comprised of making a simulation using the natural cubic spline and drawing the simulation results.
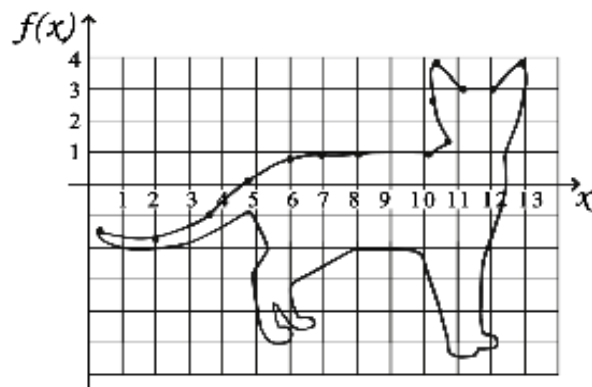
Figure 5. The cat picture is used as a reference test.

3.2.2. Graphic Data Experiment Result. On this issue, 4 dots data are provided. Students are asked to prepare a chart from 4 data points provided (Table 3). All of the running simulations were used in the worksheet train abstraction from the complex problem, algorithm automation, data analysis, collection, and representation.

Table 3. Data for Graph Drawing

x	f(x)
0.1	-0.62049957
0.2	-0.28398669
0.3	0.00660095
0.4	0.24842440

4. Conclusion

The worksheet has been produced with a problem-based learning model for interpolation material. The modifications made in this study can be used as a reference for further research on combining appropriate learning strategies in training and improving certain CT steps with specific learning goals.

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