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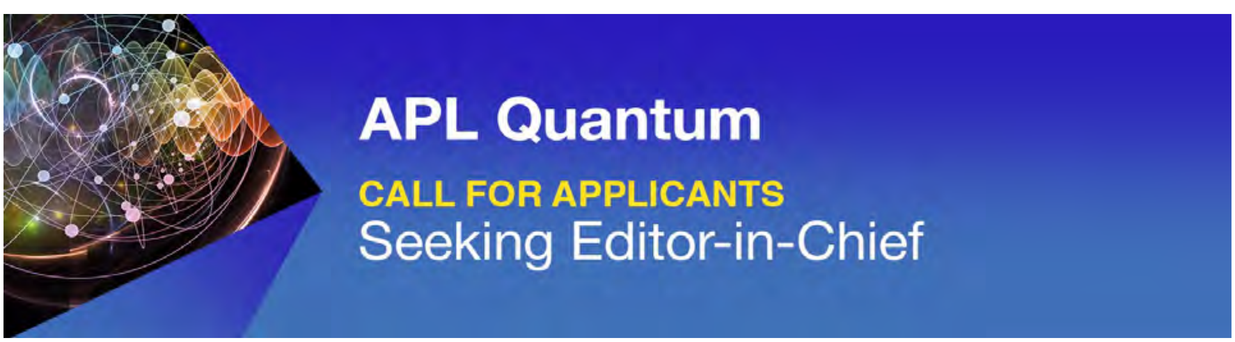

Computational Literacy Model: Solution to the Problem of Mechanical Wave Superposition

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Abstract. Students taking waves and optics courses are rarely introduced to computer programs excel and MATLAB which aim to solve problems using numerical skills. During one semester students are invited to create algorithms to solve numerical computational problems. Writing MATLAB programs in the form of m-files. Applying in problem solving. Assess and evaluate computational results in accordance with the field of computational physics of wave mechanics. One class consisting of 35 students is taught to solve problem mechanical wave, visualize and calculate numerically using a computer. Another class consist of 25 students are only taught regular learning based on analytical studies. Most of the computing class students reached 90% were able to visualize mechanical waves correctly while the analytical class averaged only 50%. Solving the superposition of waves with different phases and the same amplitude shows that almost 87% can be solved by the computational class while for the analytical class it is up to 65%. The most difficult thing is to found equation of superposition wave of difference phase and amplitude is only 50% for the computational class and the analytical class is up to 20%.

INTRODUCTION

During the last three decades the field of computational physics has grown with its state of sophistication. Many scientists consider it as the third pillar of the field of physics which is parallel to theory and experiment [1-2]. One of the main programs for learning physics is integrating phenomena and technological sophistication, especially computers, into learning programs to support the coherence of knowledge and learning practices into the curriculum [3].

Empirical facts show that the harmonization between physics and computing is a unique combination in helping students understand phenomena, analyze and solve problems related to physics content, especially wave mechanics. For example, in the late 1960s researchers at MIT developed the computational language LOGO with the aim of helping children explore physics in a Newtonian "micro world" [4]. Then, in the 1980s, Andrea diSessa developed the BOXER system. This system was successfully used to teach physics and calculus concepts to 6th graders [5-6]. Today there are so many games, applications, and simulations that utilize computing to help students learn physics, such as PhET simulations [7-8], Physlets [9,10], Hackable Tychos Simulations [11], and Exercises posted to the PICUP Online Repository. [12]. At the undergraduate level and in some curricula use computers for visualization and modeling in problem solving [13-14].

Although the implementation of computers in every line of life is so broad, computational physics has not been widely integrated into physics teaching [15-17]. Excel and MATLAB software, have a big role to help computational models in learning physics, especially wave mechanics. The adoption of logic MATLAB for numerical computing for students has its own difficulties, especially in writing a programming language (coding) which is input into the M-file program. This difficulty can be grouped into 2 types, namely the type of coding language programming and programming algorithms that are in accordance with the context of Physics.

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There are many systemic factors associated with the lack of adoption of computing into learning programs [18], but these factors should not prevent the research community in physics education from exploring computational ways of each course content. The presence of computers and computational programs produces appropriate methods and strategies that affect the effectiveness of teaching physics, and vice versa. Thus, we see the need for the development of teaching and learning theories that can address these challenges. The unique capabilities of computing must be brought into the learning classroom so that they can help solve problems, guide the implementation of computing across programs and curricula.

This paper aims to show how the role of numerical computing in solving analytically difficult wave superposition problems, especially for waves with different amplitude and phase. The computational literacy model is designed to be able to visualize graphs, analyze wave characteristics, find wave superposition solutions, and find superposition wave equations.

COMPUTATIONAL FRAMEWORK

Andrea diSessa said that the role of computing is becoming a new literacy that has an equal position with mathematics, reading and writing [5-6]. He argues that computing is increasingly being used and continues to increase its use in everyday life and professional needs which of course require new skills and ways of thinking to be able to solve problems using computing. Specific and structural steps are required such as syntax, code, algorithms, programming, computation and communication.

Based on this argument, diSessa proposes 3 important elements of computational literacy [5]. The first element is mentioned as a material element related to a computing environment concerning programming. Computational materials commonly used will ensure fluency in producing programming languages. Capability of programming literacy with a certain language will be very helpful when writing a programming language. Adequate literacy of computational materials is a requirement in using certain software. Some of the programming literacy required include writing input data syntax, writing processing logic, recognizing variables, creating functions, and making decision logic. This literacy and other instruments must be used smoothly. Integration of all components of programming literacy is required in creating a particular programming language.

The second element of computational literacy is the cognitive element. The complexity of thinking is used to understand physical phenomena and solve problems using numerical computation. Cognitive elements are closely related to procedural knowledge to input data, process data, interpret data and make correct decisions. Cognitive elements provide opportunities to understand and solve physics problems in a way that is different from previous habits. Learning models using computing provide repeated opportunities, the learning process can be repeated without having to feel bored. Imagine that calculating the superposition of waves in an analytical way requires expertise in the manipulation of various complex trigonometric formulas and requires high accuracy, of course it is very tiring if it has to be repeated. The situation is very different if algorithms have been invented and numerical formulas have been created in the programming language. Running programs can be repeated any number of times during the learning process, of course it will not be a problem.

The third element of computational literacy is the social element as said by diSessa. This third element focuses on the steps of how communication is carried out within the internal programming community. Coherence of thought is needed among community members in building a program communication language that is logically correct and scientifically conceptual from related content.

Essential Skills of Computational Literacy

The essential skills to be able to perform superposition computation of wave mechanics are built on three main elements of computational literacy [19]. Computational physics literacy is a slice of three elements that interact with each other to produce competence in the field of computer application in learning as shown in Figure 1.

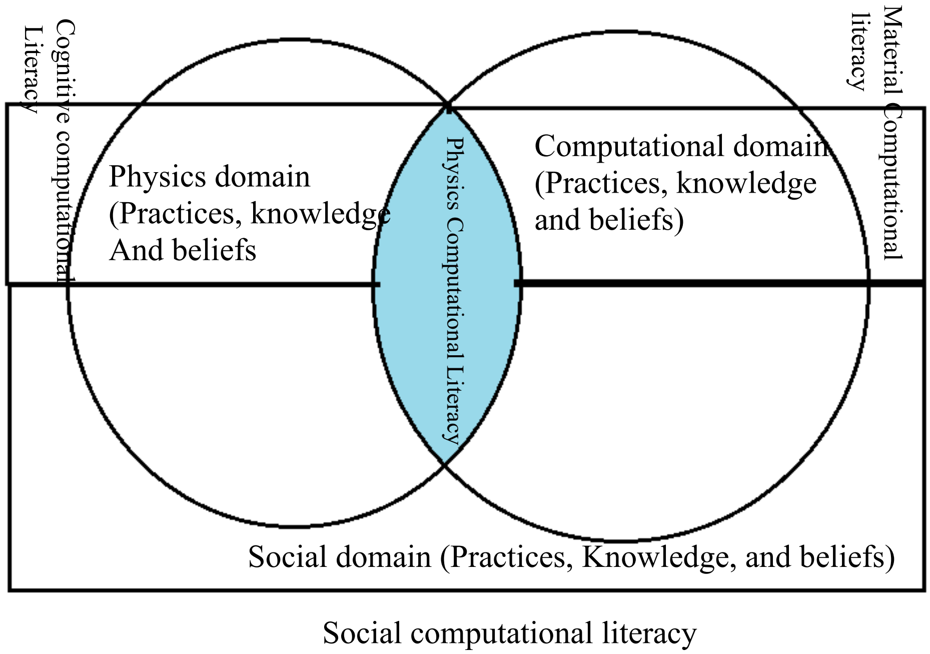

FIGURE 1. Theoretical positioning of physics computational literacy relative to physics, computational, and social domains [19].

METHODS IMPLEMENTATION

The learning process is carried out using one class that is taught analytically as a conventional class and one class using computer assistance. Learning activities that use program logic such as MATLAB are run on each student's laptop while in the laboratory using a computer with a Linux operating system. Table 1 presents the design of learning activities for the computational literacy class.

TABLE 1. Outline of computational wave superposition

Main Topic	Sub Topic	Description to Computation	Variable Computation	Model Computation
Propagation wave	1. Sine wave 2. Cosine wave	Graphically in excel Graphically in Coding	1. Amplitude 2. Phase 3. Position	Excel Coding program
Superposition	1. Superposition 2 wave amplitude same and different phase 2. Superposition 2 wave different amplitude and phase	Destructive Constructive	1. Graphical wave resultant 2. Characteristic wave resultant	Excel Coding program
Equation traveling wave and standing wave	Generating equation from graphical wave	Calculate amplitude resultant, phase, and equation		Excel Coding program

RESULTS

Wave superposition computational literacy is taught by following activities as shown in Figure 2 quadrant of the computational literacy model. Learning activities begin in the first quadrant and continue counterclockwise until the fourth quadrant. The first activity is to introduce how computer programs work to show solutions graphically or visually and numerically. At the same time explore the material content of the wave superposition analytically.

Learning activities in the second quadrant combine wave superposition analytic abilities into computer programs. Learning activities in the third quadrant are discussions to find synchronous computer and analytical programs. Learning activities in the fourth quadrant are the implementation of the use of computers to explore problem solving in wave superposition material.

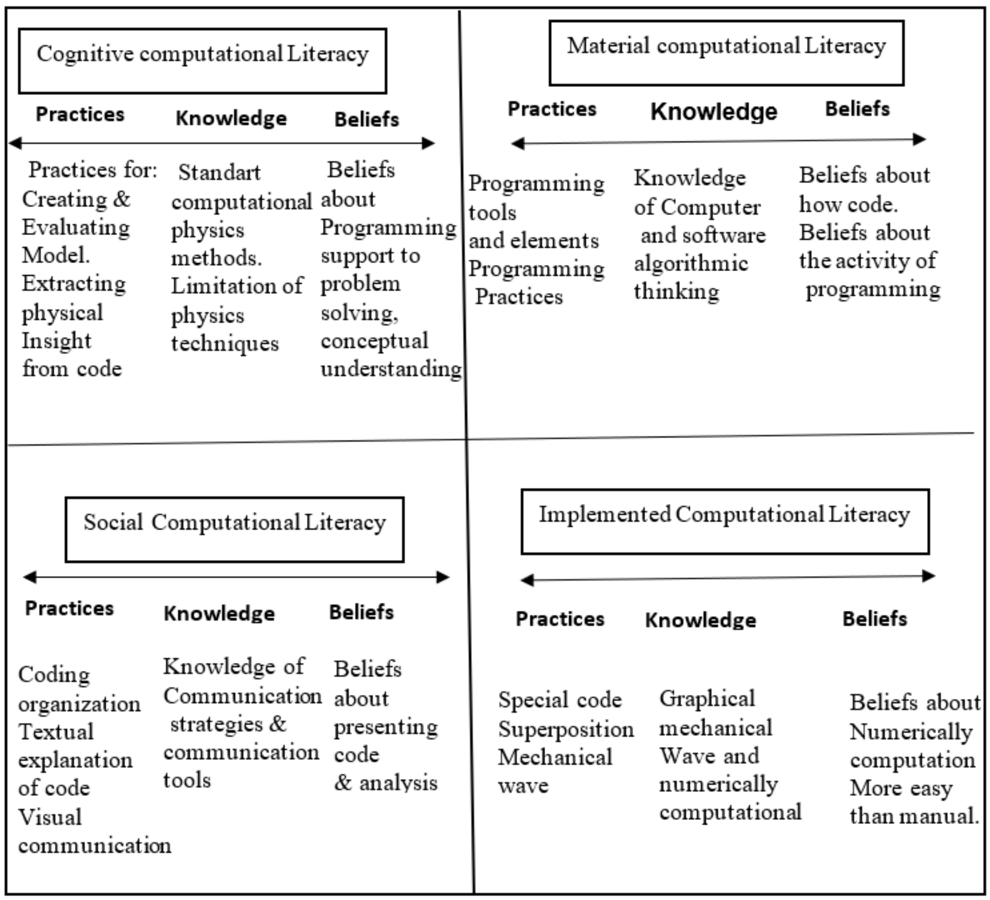

FIGURE 2. Computational literacy model quadrant

The number of students who succeeded and who failed during the research program can be seen in Table 2. The wave superposition computing class is 35 students, while the regular class is 25 students. The criteria for learning success are declared successful if they have a success score greater than 75 from a maximum score of 100.

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TABLE 2. Composition of learning outcomes for computing and analytical class

Class	Category	Visual	PS (1)	PS (2)
Computation class	Success	32 (91%)	31 (88%)	18 (51%)
	False	3	4	17
Regular class	Success	13 (52%)	16 (64%)	5 (20%)
	False	12	9	20

Figure 3 shows a pie chart for the percentage of success in computing class (SCC) for visualization competence, first problem solving (PS1) and second problem solving skills (PS2). While Figure 4 shows the percentage of success for analytical classes with the same competence.

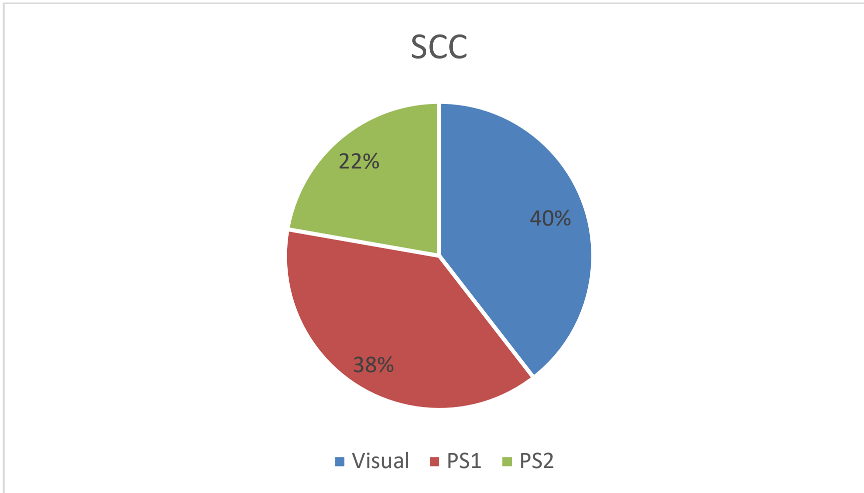

FIGURE 3. Computing class success for the three competencies

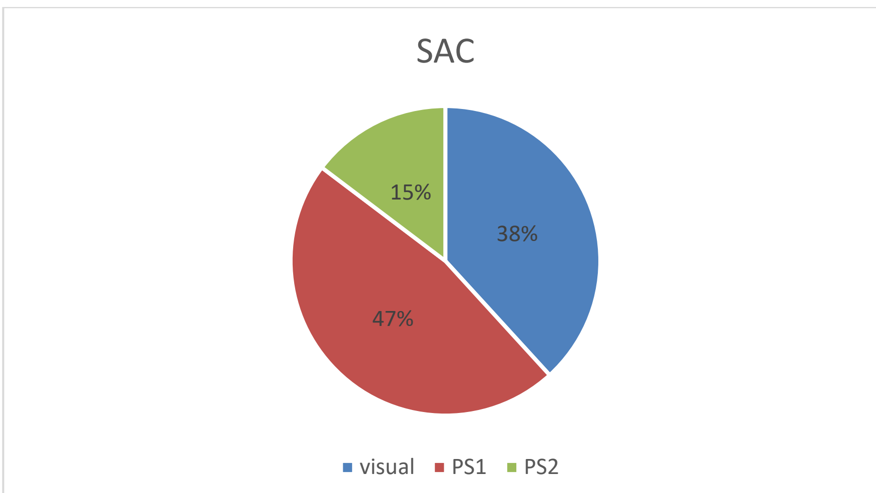

FIGURE 4. Analytical class success for the three competencies

DISCUSSION

The results of the research show that the success rate in PS1 (standing wave) competence, for computing class and analytic class, is 38% and 47%, respectively. The success of the analytical class is 9% higher in solving the superposition of mechanical waves with the same amplitude and wavelength and different phases (opposite direction). Observing these results at first glance it seems surprising, why the analytical class is more successful than the computational class with a greater chance of answering. Based on the interpretation of the data, the solution to this problem shows that the analytical class is usually trained to solve the wave mechanics equation by inputting the value of the variable into the formula that has been studied previously and the solution is immediately obtained. First experience for computing class, encountering a data set that is so large that it is confusing which is the resultant amplitude and how to determine the resultant phase, this requires time and effort that is quite thorough in order to determine the right solution.

$$y_1=4.0\,sin(3.0x\text{-}2.0t) \tag{1}$$

$$y_2=4.0\,sin(3.0x+2.0t) \tag{2}$$

$$y_3=y_1+y_2=8\,sin\,3x\,cos\,2.0t \tag{3}$$

The two wavefunctions in equation (1) and (2) move in opposite directions to produce a standing wave. In the first problem solving case (PS1), find the amplitude of the simple harmonic motion of an element located at x = 2.3 cm where x and y are measured in cm and time in seconds. The analytical solution for the superposition of two waves is a standing wave with equation (3) and an amplitude of 8 sin 3x. Of course for the analytical class did not find obstacles in answering. The direct solution is obtained by substituting the value for x to get 4.6 cm. The computational class needs to do tricks to find the numerical data of y3 and its oscillation value, the amplitude is obtained by dividing the y3 value by the oscillation value. The solution graphically can be seen in Figure 5. The programming language (coding) is written to solve the problem solving of mechanical waves. The solution to the standing wave equation is written through a program script to generate the numerical values of the wave parameters and the graphical display can be seen in Figure 6.

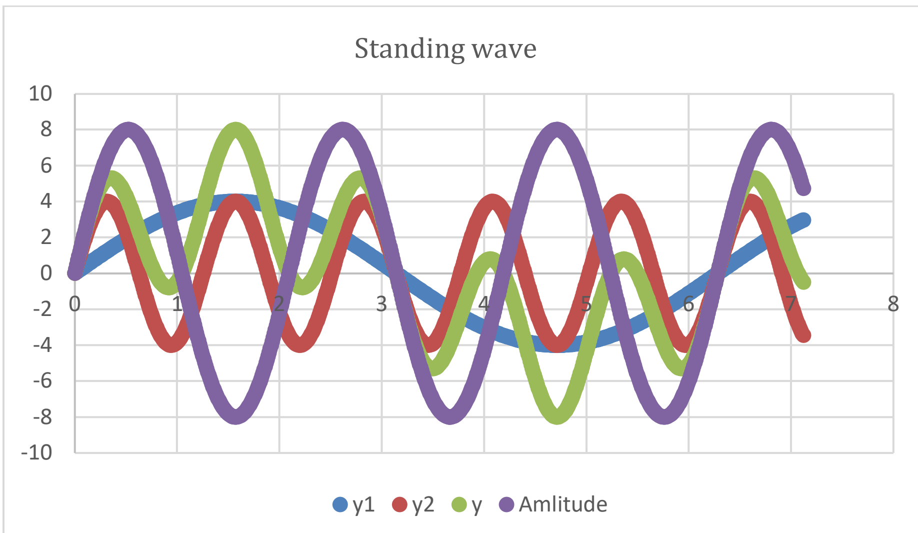

FIGURE 5. Solution for standing wave graphically

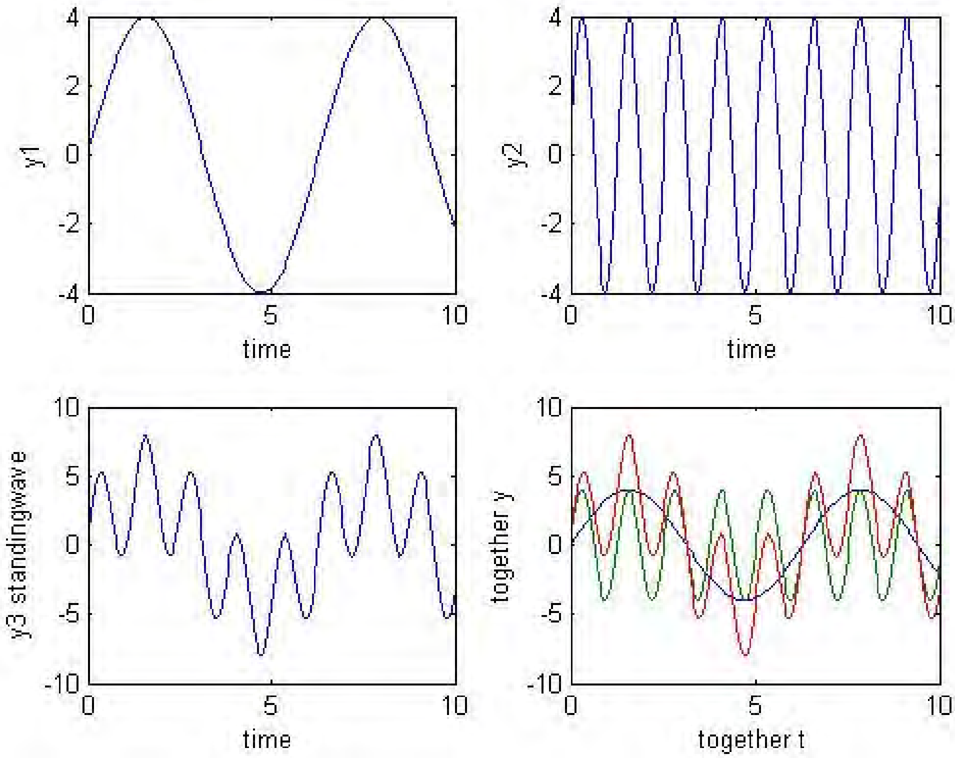

FIGURE 6. Solution graphically standing wave using coding

Problem solving type 2 (PS2) gives different results, for the computational class has a 7% chance of being superior to the analytical class. This is very logical for the case of the superposition of waves of different phases and different amplitudes easier to solve numerically with the help of computers than analytically. The work to find the PS2 solution using numerical methods is only by changing the characteristics of the wave equation. While analytically it requires mathematical manipulation which is quite inconvenient, thus the role of the computer can be equated as doing experiments but is virtual [20].

CONCLUSION

Teaching wave superposition with a learning approach that involves computational literacy is relatively superior and profitable. The advantages obtained can be seen from the precision visualization factor, the speed in producing a wave superposition numerical solution with various problem solving cases. Two basic concepts of wave superposition can be demonstrated to be adequate for this case: If two sinusoidal waves of the same amplitude and wavelength travel in the same direction along a stretched string, they interfere to produce a resultant sinusoidal wave traveling in that direction. If two sinusoidal waves of the same amplitude and wavelength travel in opposite directions along a stretched string, their interference with each other produces a standing wave.

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