THE ROLE OF COMPUTER MODELING IN ENHANCING STUDENTS' CONCEPTUAL UNDERSTANDING OF PHYSICS

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Abstract. The purpose of this study was to investigate how the use of the computer simulations program VPython facilitated students' conceptual understanding of fundamental physical principles and in constructing new knowledge of physics. We focused on students in a calculus-based introductory physics course, based on the Matter and Interactions curriculum of Chabay & Sherwood (2002) at a large state engineering and science university in the USA. A major emphasis of this course was on computer modeling by using VPython to write programs simulating physical systems. We conducted multiple student interviews, as well as an open-ended exit survey, to find out student views on how creating their own simulations to enhanced-conceptual understanding of physics and in constructing new knowledge of physics. The results varied in relation to the phases when the interviews were conducted. At the beginning of the course, students viewed the simulation program as a burden. However, during the course, students stated that it promoted their knowledge and better conceptual understanding of physical phenomena. We deduce that VPython computer simulations can improve students' conceptual understanding of fundamental physical concepts and promote construction of new knowledge in physics, once they overcome the initial learning curve associated with the VPython software package.

Keywords: computer simulations, computer modeling, learning and teaching, models, physics, VPython

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Introduction

Computers are used significantly in model creation, data logging, or creating simulations. For example, Microcomputer-Based Laboratories (MBL) is effective in improving student graphic interpretation performance (Brasell, 1987; Nachmias & Linn, 1987; Stein, 1987) in teaching science (Steinberg, 2000). The current study examines the use of computers to simulate physical relationships. There are several physics software packages that can animate the motion of objects and display information about the state of objects and motion (Scherer et al., 2000). These simulations can either be user-written or created by using icons. For example, java applets are icon-oriented programs in which students do not need to write the simulation programs. Instead, they need only to vary parameters specified by the program and edited during the simulation setup stage. In this situation, students are limited to analyzing model output instead of their own model creation based on construction of new knowledge. An alternative approach includes using the Vpython programming language, which allows students to create their own model creation by writing and varying the source code. This gives students the ability to examine and analyze more complex and practical physical systems by writing graph-oriented computer simulation programs than the small number of systems that they can treat analytically (Scherer et al. 2000). These capabilities are important since it is common for physical systems to exhibit complex behavior extending beyond analytical solution techniques; such systems cannot be analyzed without computers (Chabay & Sherwood, 1999). For these systems, VPhython is useful for employing many representations such as pictures, 2-D or 3-D animations, graphs, vectors, and numerical data displays which are effective in improving conceptual understanding of the concepts in physics. Scherer et al. (2000) say that "the VPython supports scientific visualization in three dimensions." The most significant advantage of using the VPython for teaching science is that the VPython allows inexperienced students to improve in writing computer models with visualization almost as easily as they can write the physics equations themselves. This is confirmed by Chabay & Sherwood (2008): "In doing so, students need to bring together various components of their physics knowledge; for example, identify all interactions, describe them mathematically, and correctly write and apply a small set of powerful fundamental physical principles such as the linear momentum principle in the VPython and predict the behavior of the system."

In this study, we focused on students' feedback in using computer modeling in an introductory physics course. Computer modeling plays an important role in physics courses to both solve and understand complex physical systems. The impact of using computer simulations in a college physics course depends on the details of the program such that it may require programming background that students may not have and the manner in which it is employed for teaching physics concepts. In using icon-oriented computer simulations, researchers showed that computer simulations can sometimes be effective for teaching science in terms of enhancing conceptual understanding and construction of new knowledge. Further, students can develop better conceptual understanding with computer simulations than with traditional instruction. While it is claimed that icon-oriented computer simulations can sometimes improve the effectiveness of science teaching, but it does not guarantee it. Thus the effects of using simulations are variable. Sometimes it is positive and sometimes negative. Therefore, it is suggested that teachers should be selective about deciding simulations especially with regard to when, what kind, and how to use them in their science courses (Strauss & Kinzie, 1994; Woodward et al., 1988; Vasu & Tyler, 1997; Choi & Gennaro, 1987; Sherwood & Hasselbring, 1985/86).

Structure of the course

The university physics course was a two-semester introduction to calculus-based mechanics and thermodynamics for physics majors. The fall semester covered Particles, Kinematics, and Conservation Laws (PHYS 162). The spring semester covered Mechanics, Heat, and Kinetic Theory (PHYS 163).

The interactive/dialogic approach in lecture was used as the instructor explored students' knowledge and took account of them even though they may be different from the scientific explanations (Chin, 2007). The aim was to encourage students to elaborate on their thinking and assist them to construct conceptual knowledge (van Zee & Minstrell, 1997b).

During a guided discussion in small group work and computer modeling lab, the instructor asked conceptual questions to elicit students' knowledge and to promote productive thinking. Also, he encouraged and welcomed students' responses and questions. As for providing on-going assessment, he commented on students' answers and fostered multiple answers. He did all these to develop students' construction of new knowledge based on inquiry and constructivism (Chin, 2007).

Teaching method: modeling-based interactive engagement

Modeling-based interactive engagement teaching method was used in these courses. "Modeling" as used here has a different meaning from "modeling" used in the notation of science education. In brief, modeling in physics is defined as "making a simplified, idealized physics model of a messy real-world situation by approximations" (Chabay & Sherwood, 1999). This is also called "physics modeling" in the physics education community. In this course, physics modeling and computer simulations were used to promote conceptual understanding utilizing the interactive engagement method. Hake (1998) defines "Interactive Engagement (IE) methods as those designed at least in part to promote conceptual understanding through engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors..." It is a method that improves students' conceptual understanding by their interactions with one another encouraging problem-solving and some hands-on activities. This method provides immediate feedback from discussions with their peers, teaching assistants, and/or instructors.

Modeling-based interactive engagement instruction involves physics modeling and computer modeling that focus on the development of building conceptual understanding of physical principles.

Physics modeling

The physics model in the physics-education community is “a simplified and idealized physical system, phenomenon, or idealization.” According to Greca & Moreira (2002), the physics models determine, for instance, the simplifications, the connections, and the necessary constraints. As an example one can think of a point particle model of a system in classical mechanics. Another example is a simple pendulum, which is an idealized system consisting of a mass particle on a massless string of invariant length, moving in the homogenous gravitational field of the Earth without air drag (Czudkovà & Musilovà, 2000).

In this university’s calculus-based introductory physics courses, students do not use pre-defined models. They apply the fundamental principles and create models by making a simplified, idealized physics model of a messy real-world situation by means of approximations. The results or predictions of the model are then compared with the actual system. The final stage is to refine the model to obtain better agreement, if needed. Sometimes it may not be needed to vary the model to get more exact agreement with the real world phenomena. Even though the agreement may be excellent, it will never be exact since there are always some influences in the environment that we cannot consider while we are building the models. For instance, in an experiment where a rock is falling, while it falls the gravitational pull of the earth and air resistance are the main influences. However, there are also other effects such as humidity, wind and weather, and rotation of the Earth and other planets (Chabay & Sherwood, 1999).

Based on physics modeling (Chabay & Sherwood, 1999) the procedure is summarized as follows: (i) start from fundamental principles which are the linear momentum principle, the energy principle, and the angular momentum principle; (ii) estimate quantities; (iii) make assumptions and approximations;

(iv) decide how to model the system; (v) explain / predict a real physical phenomenon in the system; and finally, evaluate the explanation or prediction.

In summary, physics modeling is an analysis of complex physical systems by making conscious approximations, simplifications, and idealizations. When students make approximations or simplifications, they should be able to explain why they make them. For instance, in modeling a falling ball, air resistance is generally neglected, thus, there is no force contribution from air resistance. While students do neglect the air resistance, they should be able to explain why the air resistance is neglected. For instance, one of the reasons is that the effects of air resistance are often very small, so it can be neglected by them for the most part of solving problems by making approximations.

Computer simulations

In this course, students write computer simulation programs to simulate physical systems using the VPython (Scherer et al., 2000). The VPython computer simulation program is suitable for Chabay & Sherwood's curriculum because students do not need to have a programming background. Chabay & Sherwood (1999) explain why the VPython computer simulation program is suitable for this type of learning environment: It is desirable that students themselves write the computer programs so that there are no impenetrable "black boxes."…It is also desirable that students produce 3-D animations of physical systems, and electric and magnetic fields, not just graphs, but in standard programming environments this has been very difficult to do, and students in the introductory calculus-based physics course are very knowledgeable about all uses of computers save one: programming…There isn't time to teach programming, much less how to do 3-D graphs, so it is essential to have a suitable programming environment that needs little instruction. VPython provides a suitable environment for the purpose.

David Scherer (Scherer et al., 2000), a student in the Matter &Interactions course at Carnegie Mellon, created VPython in 2000. The VPython program requires that students focus on physics computations to get 3-D visualizations. The VPython supports standard vector estimates, so students can represent calculations in vector form. In other words, students can do true vector estimates, which improves their understanding of the utility of vectors and vector notation. For example, students can study the motion of the earth in orbit around the sun by writing a program using VPython as shown in Table 1. Fig. 1 is the printout of the simulation.

Fig. 1 shows that a planet with a mass of ½ of a sun is orbiting sun in nearly circular orbit while the sun does in its orbit. While students write their own computer simulation programs and can vary the mass of the sun and the mass of planet, they need to correctly implement the appropriate physics. In this example, students can understand how the gravitational force law, $F_g = \frac{Gm_1 m_2}{d^2}$, applies to the Sun and the planet, and how the momentum principle, $\vec{P}_{new} = \vec{P}_{before} + \vec{F}\Delta t$, is applied. In the gravitational force expression, G is the universal gravitation constant, m_1, m_2 represent the masses of two objects (the sun and planet in this example), and d is the distance separating the objects centers. This is a relevant example of complex behavior emerging from simple physics principles, in this case the momentum principle and the gravitational force law. This example reflects the power of fundamental physics principles and gives a graphic example of the time evolution character of the momentum principle. An example is shown in Table 1.

Creating simulations by the VPython develops students' conceptual understanding of fundamental physical principles and skills at solving a variety of problems because they can view how physics principles work and make the connections between the formalism of integral calculus and the procedure of adding up quantities (Chabay & Sherwood, 2008). In order to explore students' views about how such computer simulations affect students' conceptual understanding and promoting students' knowledge of physics, interviews were conducted with volunteer students and an open-ended exit survey was administered.

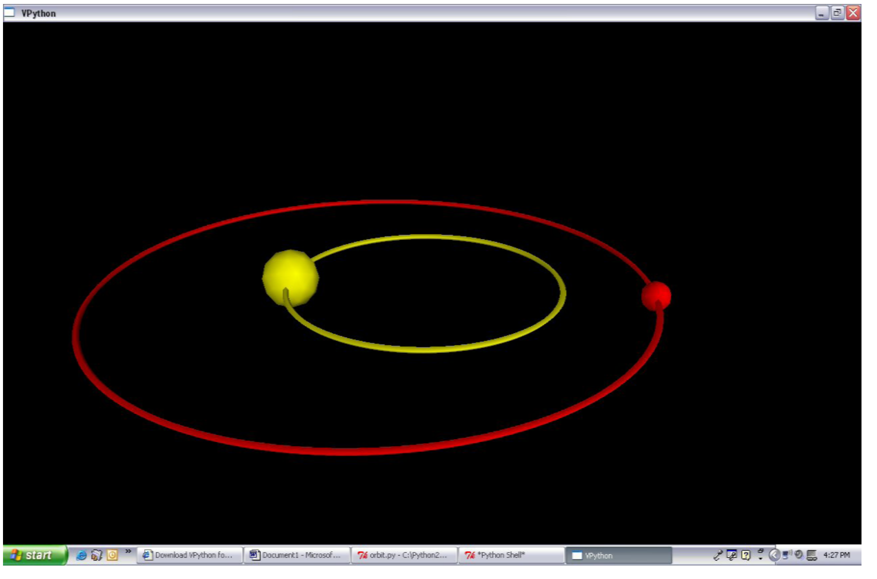

Fig. 1. Visualization for the VPython planetary orbits (Ornek, 2008)

Table 1. VPython Program for Producing a Real-Time 3-D Animation in Figure 1 of the Earth Going in Orbit around the Sun (Ornek, 2008)

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1. from visual import *
2. sun = sphere()
3. sun.pos = vector(-1e11,0,0)
4. sun.radius = 2e10
5. sun.color = color.yellow
6. sun.mass = 2e30
7. sun.p = vector(0, 0, -1e4) * sun.mass *[initial momentum of the sun]*
8. earth = sphere()
9. earth.pos = vector(1.5e11,0,0)

10. earth.radius = 1e10

11. earth.color = color.red

12. earth.mass = 1e30

13. earth.p = -sun.p

14. for a in [sun, earth]:

15. a.orbit = curve(color=a.color, radius = 2e9)

16. dt = 86400

17. while 1:

18. rate(100)

19. dist = earth.pos - sun.pos *[distance between the earth and the sun]*

20. force = 6.7e-11 * sun.mass * earth.mass * dist / mag(dist)**3 *[the gravitational force law between the sun and the earth]*

21. sun.p = sun.p + force*dt *[updating the momentum for the sun]*

22. earth.p = earth.p - force*dt *[updating the momentum for the earth]*

23. for a in [sun, earth]:

24. a.pos = a.pos + a.p/a.mass * dt

25. a.orbit.append(pos=a.pos)

26. print

Note: The explanations in [ ] in Table 1 are physics relationships that must be set by students. Setting up these physics relationships is the model-building step.

Purpose of the study and research question

The purpose of this study was to investigate students’ views of the role of writing programs to simulate physical systems in constructing knowledge of physics. The focus of the study was: what were students’ views and expectations of the role of computer modeling in enhancing conceptual understanding of physics and constructing knowledge of physics by means of modeling-based instruction and interactive engagement?

Research method

Subjects and settings

We conducted this project by involving students enrolled in Purdue's PHYS 162 and PHYS 163, the two-semester introductory-physics sequence mainly populated by physics majors. We conducted the first interview with 16 volunteer students in the fall, 2004, in PHYS 162. At the beginning and the end of the spring, 2005, we conducted the second and third interviews with 6 volunteers from the original group of 16. There were several reasons why we lost some of our interview participants. A few of interviewees were majoring in engineering. They were taking PHYS 162 because it counted as an honors course. However, their engineering course and PHYS 163 were at the same time in the Spring, 2005. The physics department and engineering department decided that Physics 162 was adequate to count for Physics 152, Mechanics for science and engineering majors, instead of having to take both PHYS 162 and 163; thus, there was no need to take Physics 163, so they dropped the class. One student had not decided about his major, so physics was something he picked up just to have a major to start with.

Theoretical framework for the study: Phenomenography

Since this study is concerned with student experience of the role of computer modeling to improve conceptual understanding of physics and constructing knowledge of physics within an introductory physics course, the design of this qualitative study is viewed within a phenomenographic framework.

Phenomenographic framework is the study of the different ways in which people experience the world. In other words, its aim is to discover the range of ways people in a group experience, conceptualize, notice, and understand various aspects of phenomena in the world around them (Bowden et al., 1992). In phenomenographic research, the researcher chooses to study how people experience a given phenomenon. Phenomenographic framework is used to ascertain how students understand selected concepts and principles of physics (Bowden et al., 1992).

Data collection and analysis

We began the data collection by recording all interviews and transcribing them. The transcripts of interviews were first read several times to get a sense of the data corpus. Since we wanted to probe students' views about the role of computer simulations understanding and constructing knowledge of physics, first we decided to focus on computer simulations. Tentative codes were developed by making descriptive phrases from the pilot study. These codes were then refined until a useful and complete system emerged from the main study that covered entire database (Patton, 2002; Miles & Huberman, 1994).

Besides students' interviews, there was an exit survey at the end of the course. The exit survey explored students' thoughts about the course and the way in which it was taught. The exit survey was adapted from Churukian's (2002) study and adapted to fit within our own research goals. We used the responses of 27 students who granted consent to use their surveys. The questions and most frequent responses by students were summarized.

Two types of triangulation were used to establish the credibility of the results. One was to involve another investigator's interpretation of the data independently (Patton, 2002). We compared the findings and found that our results were compatible. The latter was to include the primary data in the results. The inclusion of excerpts from the interviews in the results allows the reader to see exactly the basis upon which our conclusions were made.

Results

The transcripts and quotations from the exit survey contain the following shorthand notation: [ ] represents comments about the interview added after the fact, {…} indicates that unimportant words were omitted from the transcript, and inaudible words or sentences were not included. Names used are pseudonyms.

Examining the interview data gave a deeper understanding of the students' conceptions of the course about lecture, small group work, and computer simulations. First, all three interview results were examined. After that, only five students' interview results were examined from the first, second, and third interview because only five of 16 students were involved in the first, second, and third interviews throughout the course. A few quotes were selected to support assertions. Because of space constraints, these quotes chosen from the interviews are representative of other students.

The data were analyzed into the following subcategories: expectations; instructions, programming background, and difficulties; understanding, learning, and visualization; traditional lab vs. computer simulation lab; writing computer simulation programs vs. using icon-oriented computer simulations.

Expectations

Students come into a course with expectations of how it would be conducted, what would happen, and how they would interact in the class. In this case, the expectations concerning parts of the course were different. For instance, the following quotes referred to her expectations:

Suzan: Um, yes and no. I didn't expect all the computer based simulations I didn't- um, like I said I expected the labs to be more hands on. I didn't realize that it was a computer based thing, which is cool 'cause [because] I like computers. Uh, I like computer programming and it's really cool to be able to program something and have it actually work. Um, other than that it's basically what I expected. Except that it's not as boring and confusing as I thought it was going to be (Fall 2004).

The students spoke about the expectation of having a regular lab which they can manipulate experiments and take measurements. Students did not expect a lab based on computer software (VPython) that requires students to write their own programs. They were generally pleasantly surprised. Suzan's phrase of "computer programming was useful to be able to program something and had it actually work" describes what other students experienced as well. In addition, they were surprised that they had neglected something such as friction by means of making models and considered how these work using some approximations. Students obtained firsthand experience of how these models were created. For instance, in Suzan's comment, the purpose of neglecting air resistance and friction makes sense since the aim is to simplify the complex model.

Instructions, programming background and difficulties

Students' responses revealed that the level of background knowledge needed to improve the VPython programming language. In their comments, they spoke about needs that were or were not met. The following quotes referred to the effects of not having enough instructions about how to write VPython simulation code and not having enough background in computer programming. As a result, students encountered difficulty when writing VPython program.

Jennifer: … the computer simulations and that's it's a new language and it's a daunting to just be thrown in to it…make it- just have a little more introduction to how the computer programming aspects actually work, um, before jumping into it (Fall 2004).

Aaron: Computer simulations are just really tedious. I think it's kind of unfair for people who don't have any computer programming back ground (Fall 2004).

Students generally stated that the instructions provided were not enough to learn the computer simulation program. Since it was a part of the course, they needed to have more instructions about how to use the program. Besides this, it was difficult to improve it if they did not have a computer language programming such as C++. Their comments generally reflected that the lack of instruction and background programming knowledge be a major barrier within the course.

Also, students revealed that the lack of having computer programming took them away from physics concepts since they had to deal with both programming and physics.

James: …They [computer simulations] take away from the concepts. Because you have to learn how to do the simulations and you also have to learn how to do the physics. It would be easier for me to sit down with a pencil and a paper and work out these problems just, you know, with my own knowledge instead of having to program them into a computer. And, uh, on his [the instructor] last test I got myself caught in to a trap in this class where I studied on not how or why these concepts work. I just studied how to make them work because I wanted to make them work on the simulations. This hurt me because I didn't fully understand and appreciate how they work. And so on the test I wasn't able to, um- I wasn't able to, uh, articulate my thoughts and that kind of thing as... I take this as a fault of my own as not studying properly, but it was, you know, why I don't like the simulations so much (Fall 2004).

Understanding, learning and visualization

Some students revealed their difficulties in understanding concepts and constructing knowledge of physics when they needed to write a computer simulation program of a physics problem. In their comments, they talked about having trouble in this kind of learning environment because it was difficult to write successfully source code and run the programs. On the other hand, they commented that this learning style helped them to visualize what was happening. The following conversation ensued between Thomas and the interviewer.

Interviewer: You used this computer simulation to study the movements of the planets in orbit about the sun. Was it effective to understand the usage of fundamental principles and the motion of a planet around a sun, such as our Earth around our sun?

Thomas: Actually, I wouldn't say so. I had more trouble trying to figure out the code and what was required in order to get the code to run properly. I was- I was already pretty familiar with orbits and planetary motion. So, no, it wasn't very helpful.

Thomas: I don't think it [computer simulations] really helps me to understand physical phenomena. It helps me visualize it, that's for sure. Uh, I didn't- generally find it just to be tedious work where you have to code everything, since I have no like idea how to do any computer- computer programming before this class. So for the first two, I thought they were very useless. And then afterwards they got fairly easier when I started to understand, but at this point I don't really see how they can really help you understand physics (Fall 2004).

Even though some students thought that computer simulations did not facilitate in understanding physical phenomenon and to construct physics knowledge, actually, their comments interestingly revealed another result which was that it helped them to visualize the physical phenomenon. In other words, visualization assisted them to understand what was happening in a physical phenomenon. For instance, the following quotes indicated that computer simulations provided them in visualizing a physical phenomenon such as vibrating atoms, or orbital motion.

Suzan: I think it [computer simulations]'s really helpful. I have trouble visualizing like atoms vibrating and the different kind of- I like things that are big that I can see. Like stars and planets I can understand their motion. But we deal a lot with big system things down to the particles and atoms and I have trouble visualizing that when I'm just sitting there thinking about it. But, um, when you do use the Vpython to program it simulates, you know, here's two atoms vibrating. I find that really helpful (Fall 2004).

Clark: Computer simulations help because some of the concepts, some of the things we can't visualize, like how two particles interact, things like that. That's how the computer simulations help (Spring 2005).

Another significant comment made by students was concerning the use of computer simulations in constructing physics knowledge and conceptual understanding of physical phenomenon. Students thought that computer simulations aided in gaining new perspectives and in exploring theories using models. Also, it provided in solving problems which they perceived to be too difficult. In their comments, they addressed a different learning style based on visualization by using computer simulations and on how to use it. Viewing concepts applied to write computer simulations and constructing new knowledge or applying new knowledge all contributed to learning, understanding physical phenomenon, why the equations were used and how they were related. They also enjoyed writing computer simulations. Here are several quotations that indicated these ideas.

Suzan: I really liked the computer simulations. I think it's really cool that, uh, that you can, um, - you know if you know the force and you know the first position you can write a program that will have a little balls on the screen that goes through a fence kind of. For a hydrogen atom to be interacting the way they would. Um, I think that's a really, really neat that you can solve problems that way instead of having to do all the minute little calculations for the answer (Fall 2004).

Mark: Um, well, like we had to do an orbital program like the Earth rotating about the Sun or two stars rotating about each other. It was helpful to see how you can calculate step by step by step these things and how that works and everything. How the forces change and motions and everything. It was good to see because we read about it (Fall 2004).

Mark: "Um... That's- the computer simulation's really cool because, uh, it lets you understand stuff on like, uh- how am I going to say- the lower level. Like just by doing it you have the calculations over and over again. Which if you did that by hand that would be like insane. And it would just take way to long. But it kind of lets you use like- it seems most of the time for computer simulations to like the step below what we're like working on. Like using- or were using momentum and forces to graph energy now. And so it lets you kind of buy that and run that through and then see how it apples to the next step. It seems- it kind of seems how it's going so far" (Spring 2005).

Traditional lab vs. computer simulation lab

Students revealed strategies they preferred to assist them in understanding concepts and applying what they constructed in a lecture. In their comments they spoke of their own learning styles and how those styles were or were not addressed. Having only a traditional lab allowed students to manipulate materials, apparatus, and tools, or having only what a computer simulation lab allowed them to do some experiments which could not be done by using a regular lab. Having access to both of these resources allowed students the ability to apply two different methods to learn concepts. Here are several quotations that state students' preferences regarding the different lab styles.

Interviewer: Do you prefer having a traditional physics lab, computer lab, or both of them together?

Thomas: Umm [pause]. I probably like to have a little bit of both. I mean it's good that because like when we go on, we continue with physics, we will be using both. There is a good chance we will use the computer and an actual experiment so it is probably good to get experience in both. I can see wha… sort of why we don't like have a lab for this class. Not a computer lab but like a regular, a traditional lab because it is kind of hard to do labs based on the microscopic stuff we've been talking about (Spring 2005).

Students' learning styles varied and could not be accommodated all the time. However, access to a computer simulation lab was at least one method of meeting some students' learning preferences.

The following comment was remarkable in that the student had one feeling about using computer programming and his notes, and yet the end result told another story.

John: Mmm, I guess I learn more toward traditional, like I'm not totally comfortable like using computer programs yet but it's probably good that we're doing them cause we're gonna have to be using them if we're going into a physics field. So, it's alright, I don't know (Spring 2005).

The student revealed a noteworthy point with regards to future studies in a physics field. He was aware that using computer programming was important in physics even though he was not comfortable using computer programming. In his comment, he stated that having experience with computer simulation program provided benefits in students' future endeavors since computer simulations are widely used in physics discipline as for conducting experiments to solve complex problems.

Writing computer simulation programs vs. using icon-oriented computer simulations

When considering teaching methods, the choice for utilizing computers as a part of a course was a big decision for an instructor. The most useful way of using computers was to have students apply conceptual principles such as the linear momentum principle in physics instead of just collecting data or changing parameters by icons. It was important for the students to visualize how to use these principles and to develop the appropriate methods for applying them. Here are some comments from the participants about writing their own computer simulations vs. using icon-oriented computer simulations.

Elizabeth: I love it [writing own computer simulations]; I think it's so fun. It's a neat way to reinforce physics concepts that we've been learning (Spring 2005).

The following conversation ensued between Thomas and the interviewer to discuss why he preferred to write his own computer simulations instead of icon-oriented computer simulations.

Interviewer: How do you like creating your own computer simulations?

Thomas: [Pause] Umm, I like it, it's kind of hard when you have to debug the thing, it's kind of frustrating to debug it when there's just one problem, like one of your answers gets messed up because you like made a typo or something but other than that I think you get a good understanding of what is going to happen, like a real life problem.

Interviewer: Did it help you understand concepts you did not understand before?

Thomas: Wells it's helped review the concepts, I am not sure if it's like helped teach me stuff I did not understand before like to be able to do the code you have to be able to understand like the problem before or else you probably won't be able to write the code right and then the simulation won't be right and you wouldn't have done anything.

Interviewer: Do you prefer having computer simulations that are ready for you? Like changing parameterrs?

Thomas: It's probably better to use the VPython because then you actually get to know like process how to solve that problem, like if you are just using icon oriented, all you have to do is change it, its just numbers. You don't learn anything about the concepts behind it or anything like that (Spring 2005).

The following talk between Jennifer and the interviewer was about why she did prefer icon-oriented computer simulations instead of writing her own computer simulations.

Interviewer: Do you prefer taking a traditional physics lab or computer lab or both of them together?

John: Umm, by traditional do you mean like experiments and stuff?

Interviewer: Yeah, experiments

John: Yeah, I like experiments and stuff better than computer [laugh].

Interviewer: So do you prefer it?

John: Yeah, yeah I prefer that.

Interviewer: How do you like creating your own computer animation?

John: Nah, I don't really care for that way, it's, yeah, something I have to do, and then I do it [Laughs], or try to at least.

Interviewer: Does it help you understand concepts you did not understand before?

John: Umm, I guess it's supposed to but, I don't know, there's that little paradox, you have to know what's happening first to program it before you can see what's happening so yeah…

Interviewer: Do you prefer having computer simulations which are ready for you, I mean already written?

John: Already, yeah, yeah because then you can see what is happening. I don't mind that, that's cool (Spring 2005).

Another example from the excerpts indicated that John also thought that writing his own computer simulations was effective.

Aspects of the role of computer simulation programmes				
Before		**After**		
Expectations of students on the role of computer modeling	Difficulties in terms of writing computer modeling programs	Constructing physics knowledge, Understanding and visualization of physical phenomenon	Traditional lab vs. computer simulation lab	Writing computer simulation programs vs. using icon-oriented computer simulations
• No expectations on the role of computer simulation labs in learning and understanding physics before coming to this course.	• Lack of programming background • Lack of instructions on how to write computer modeling programs	• Providing an application of the knowledge to real world situations. • Seeing how things are applied in the real world instead of just looking at equations. • Assisting students construct and understand physical phenomenon. • Providing construction of models which can explain and predict a wide range of physical phenomenon using a few powerful fundamental principles.	• Computer simulation lab can provide students enhance conceptual understanding of physics • But sometimes students thought that it was better to manipulate materials, apparatus, and tools if they had a traditional lab. • Being aware that computer programming was important in the field to assist students' constructing and understanding of physical concepts.	• Preferring computer simulation programs to apply physics principles • Preferring to write their own simulations • Students can analyze the systems • Applying the principles which have physical meaning and interpretation.

Table 2. Students' views on the role of computer simulation programmes in physics

Interviewer: How do you feel about creating your own computer simulations?

John: I like it when they work. Uhh, it's interesting and sort of difficult because like this isn't like programming class physics class, so you don't want to spend a lot of time teaching syntax if we do its only a loss of our own. But uh, it's helpful in some ways; just you know visualizing it and seeing how it works out in real life

Interviewer: Does it help you understand concepts you did not understand before?

John: Umm, yeah last semester it really helped me understand the whole orbiting of the planets and the whole the orbiting of the planets and how the change in momentum and the force direction, how all of that worked (Spring 2005).

A significant and surprising result of these interviews was that most students did not choose having ready-made computer simulations which were icon-oriented (except for one student). In icon-oriented computer simulations, students could only change parameters such as velocity, or acceleration. They could not do more than that. However, the VPython computer simulation program allowed students the capability to write their own simulation programs and constructing dynamics 3D visualizations by using the basic physics principles such as the linear momentum principle or the energy principle.

Conclusions and discussion

In this study, the objective was to seek students' views about the role of computer modeling in constucting physics knowledge and conceptual understanding of physics based on modeling-interactive engagement course. The results summurized in Table 2 showed that students did not have any beliefs and expectations of the role of computer simulation labs in understanding and construction of physics knowledge before coming to this course. Students' reactions were not all positive in using computer simulations, especially at the beginning of the course. However, throughout the course, they changed their initial responses as they became more sophisticated in constructing computer programs. In general, they initially believed they did not possess the needed skills for creating sophisticated computer simulations because they had not previously participated in computer simulation labs of this kind. Some student concerns regarded the perceived lack of instructions on how to use the computer simulation program and lack of computer programming background. They stated that these deficiencies caused difficulties in mastering major programming skills such as knowledge of syntax and program structure (Chabay & Sherwood, 2008). Therefore, students thought that it affected their construction of physics knowledge and conceptual understanding of the physics concepts because they claimed that they needed to concentrate mainly on the programming language instead of physics. However, because the VPython provides a suitable programming environment and requires little instruction, having computer programming background was not a prerequisite for this course. Despite the negative aspect of programming which students perceived at the beginning of the course, students pointed out that it assisted them to construct physics knowledge, understand, and visualize the physical phenomenon. They thought that visualization of the abstract quantities exposed them to understand what was happening in a physical phenomenon by bringing together various components of their physics knowledge such as identify all interactions (e.g. potential energy is interaction energy of pairs of particles, the internal work done by all pairs of particles in a system on each other or charges make fields, fields affect other charges).

Having a regular lab in addition to the computer simulation lab could provide students to construct and understand physics knowledge because sometimes they thought that it was better to manipulate materials, apparatus, and tools. But, they were also aware that computer programming was important in the field. So, it seemed that it could promote students' construction of physics knowledge and conceptual understanding of physical concepts. Overall, most students preferred writing computer simulation programs to using icon-oriented computer-simulation programs. They claimed that they could apply the fundamental physics principles such as the linear momentum principle and write all of the computational statements to create their own simulations; therefore, creating their own simulations can provide the advantage of getting the students to do physics in an exploratory and constructive way that makes them construct knowledge of physical phenomenon and understand physical concepts (Hwang & Esquembre, 2003).

Creating computer simulations by writing programs promoted students' understanding to construct and understand physics knowledge, and visualize the physical phenomena. They thought that visualization helped them to understand what was happening in a physical phenomenon. They affirmed that computer simulations had an important role for constructing and understanding physics knowledge.

The findings of this study have important implications for physics educators that aim to promote students' construction of physics knowledge, enhance students' conceptual understanding of physics content and improve students' skills of solving a variety of physics problems. These are expected as usual outcomes of introductory physic courses. Integrating an appropriate computer modeling program into an introductory physics course has the potential to contribute significantly to developing in these areas (Chabay & Sherwood, 2008). Chabay & Sherwood has suggested that writing computer programs can animate the universality of fundamental physics principles (the linear momentum principle, the energy principle, and the angular momentum principle), thus, building conceptual understanding of physical principals that promotes conceptual understanding of physical phenomena. For example:…Students who write a program to simulate Rutherford scattering sometimes spontaneously comment that their computation is essentially the same as their earlier modeling of a binary star, despite the quantitative difference between the gravitational and electric force, and a difference scale of 10^{23}.

Integrating computation in particular computer modeling programming into an introductory physics course may not be easy task. It may require that instructors provide scaffolding activities that assist students to implement and visualize physics models and solve physics problems (Kohlmyer, 2005).

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