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Exploiting IT Simulations for Interactivity, Thinking and Assessment in Science Education

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Abstract

This paper will review the use of computer simulations in science classrooms and then introduce internet-based simulations. The paper will discuss one way of using IT simulations that conforms to a constructivist approach in science education. Elements of interactivity, thinking and assessment are introduced with the use of such IT simulations. Based on the performance of pre-service science teachers on a floating and sinking simulation, an assessment of their conceptual understanding and specific IT skills will be discussed. The paper will conclude by suggesting that the use of IT simulations should not replace laboratory experience.

Introduction

A number of educators (e.g., Van Dusen, 1995) have suggested that a revolution is occurring in education today, albeit a technological one. While there are strong advocates of the potentials of enhancing learning with intelligent technologies like the use of computers and artificial intelligence (e.g., Lockard, Abrams, & Many, 1994), there are also those who are doubtful of the impact of computers in education (e.g., Settlage, 1995).

However, in recent years, we are left with little doubt that IT will be here to stay for the long haul in most developed and developing countries. This would be true whether in business or in education. While in the past many educators may question the value and pedagogy involved in using IT, more educators are now concerned with how best to exploit the power and potential of such a tool.

Rodrigues (1997) had conducted a review of research findings on the impact of computer-based technology in teaching and learning science. In her review she had identified and described various ways IT could be used in the science classrooms. One such use is computer simulations. IT simulations are applications that represent physical systems and processes.

In this paper, I will suggest that IT simulations will comprise of computer simulations and internet-based simulations, for want of better terms. Computer simulations are those that are available on diskettes and CD-ROMs. They are platform dependent. Internet-based simulations are platform independent and can be accessed using internet browsers. A brief review of the use of computer simulations and their related research will be carried out first. This will be followed by a discussion on how an internet-based simulation could be exploited for interactivity, thinking and assessment. The approach adopted conforms to constructivism in science education. Some science educators may even wish to suggest that it is scientific constructivism (e.g., Redish, 1999). Redish used the term scientific constructivism to emphasize the view that all knowledge building has to be done in the context of a discipline. In this case he is referring to the discipline of science.

Use of Computer Simulations in Science Classrooms

The potential for combining sophisticated visual and graphics display with other features of the microcomputers has been recognized as very promising by science educators for some time. For example, when combined with the interactive capability of the microcomputer, good simulations may provide students with meaningful opportunities for thinking, problem solving and decision making. Students could be actively involved in identifying variables, defining hypotheses, and determining methods of measurement, treatments, procedures, and proposed techniques of data analyses. Such simulations can also allow students to examine models and relationships of the real world under controlled conditions. Tamir (1986) had recognized such a potential for quite some time.

Other science educators have suggested that simulations allow for experiments that would normally be impossible due to safety, access, magnitude or time constraints (e.g., Steed, 1992) and experiments that do not conform to the laws of nature (e.g., Scanlon, O'Shea, Smith, Taylor, & O'Malley, 1993).

Examples of research studies that deal with the effectiveness of simulations are summarized below. Based on their results, Shaw and Okey (1985) concluded that laboratory activities, simulations, and a combination of these two strategies yielded higher achievement than did conventional instruction on the process skills of observing, hypothesizing, testing, classifying, and recording data. They also found that students with middle and high levels of logical reasoning performed better on such process skills than students with low level of logical reasoning ability.

Bourque and Carlson (1987) examined hands-on activities and computer simulations in chemistry. Three laboratory experiments (acid-base titration, determination of the equilibration constant of a weak acid, and determination of Avogadro's number) were designed to correspond to three computer simulations. The data indicated that the hands-on activities produced higher scores for the acid-base titration and for the ionization constant, and no significant difference for the determination of Avogadro's number. The results further showed, however, that the highest cumulative scores were achieved for the format where hands-on experience were followed by the computer simulation for the first two experiments, but there was no apparent advantage in the sequence of performance for the derivation of Avogadro's number.

Rivers and Vockell (1987) studied computer simulations used by high school biology students in attempts to enhance their problem solving skills. The simulations were administered under two conditions: guided discovery, and unguided discovery; with the control group receiving no simulations. The results indicated that: (a) students using the simulations met the unit objectives equally well when compared to the control students, and (b) students using the guided simulations surpassed the other students on subsequent simulation pretests on tests of scientific thinking, and on a test of critical thinking. The evidence suggested that students using the computerized simulations were developing generalizable problem solving strategies that could be transferred to novel settings.

Geban, Askar and Ozkan (1992) found that students using the simulation problem-solving approach achieved significantly better results in chemistry content and science process skills. They found improved attitudes among this group of students.

Lazarowitz and Huppert (1993) in their study using a biology simulation also appeared to concur with earlier studies that simulation allowed students to develop and acquire science process skills.

Hennessy, Twigger, Driver, O'Shea, O'Malley, Byard, Draper, Hartley, Mohammed and Scanlon (1995) found that students using a simulation on mechanics showed more sophisticated reasoning than their counterparts who did not use the simulation. Existence of alternative conceptions on motion was detected.

Ronen and Eliahu (1997) suggested that simulation-based activities can be used to address students' common difficulties in a particular science topic.

Internet-Based Simulations

In all the above studies, the use of simulations has been restricted to software that is available in diskettes and/or CD-ROMs. This is not surprising given that the internet came on at a later stage. However, given the increasing presence of the internet, we will need to evaluate its impact on education. Information technology has evolved to a stage where the use of the Internet for various interactive applications has become almost inevitable. Of course this does not mean there are no existing drawbacks.

Presently, there are at least two main types of internet-based simulations available for science educators to exploit viz. Applets and Shockwave/Flash simulations. The two types of simulations employ different programming languages.

Applets are simulations that use the Java programming language and can be launched with java-enabled internet browsers. Some locations where one can find such Applets are given below:

http://www.phy.ntnu.edu.tw/java/index.html
http://home.a-city.de/walter.fendt/physengl/physengl.htm
http://www.lightlink.com/sergey/java/

One example of an applet is the following thin lens applet (Figure 1) that allows one to change various properties of an object and also the different types of lenses and mirrors together with their focal lengths. It is available at http://www.phy.ntnu.edu.tw/java/Lens/lens_e.html

Shockwave/Flash simulations are simulations that are created using Macromedia software. In order to launch such simulations, one needs to ensure that the Shockwave and Flash players are installed on one's computer. These players are freely available at http://www.macromedia.com. Some locations where one can find such simulations are given below:

http://www.explorescience.com/
http://ippex.pppl.gov/interactive/
http://www.glenbrook.k12.il.us/gbssci/phys/shwave/index.html

An example of a Shockwave simulation is the following density simulation (Figure 2) that allows one to measure the mass and volume of an object and then determine whether it will float or sink in a pail containing a liquid whose density can be varied too. It is available at the following website:
http://www.explorescience.com/activities/Activity_page.cfm?ActivityID=29

While such internet-based simulations allow for active and interactive hands-on activities, they have the potential to enhance thinking and learning only if creative teachers can complement them with minds-on activities. Yap (1997) has encouraged such a minds-on approach. A successful technology-enhanced environment should encourage learners to use its resources and tools to process information deeply and to extend thinking (Kozma, 1987).

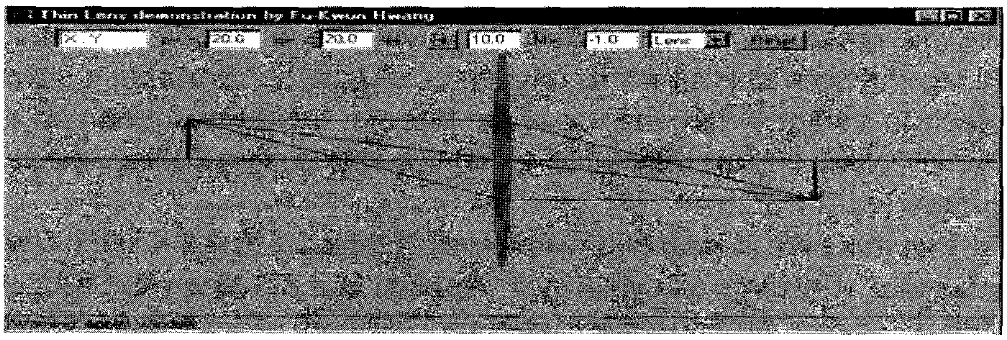

Fig. 1. Thin Lens applet.

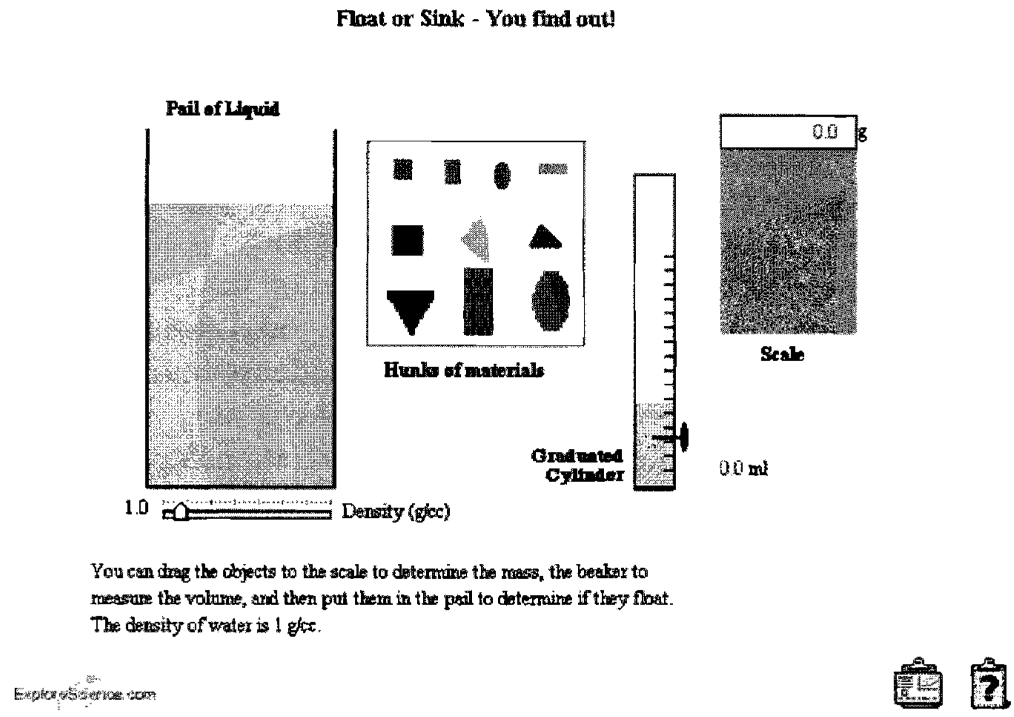

Fig. 2 Floating and Sinking Shockwave simulation.

Such internet-based simulations also have the potential to (1) increase opportunities for individualized or guided learning, (2) provide global access and hence global collaborative and cooperative learning, (3) accommodate different learning styles, and (4) provide an alternative assessment mode.

Exploiting Internet-Based Simulations

Initial internet-based simulations were mainly created by programmers or those who took great pride in their own programming prowess. They may have a background in the science discipline but were not necessary teachers themselves. They found great satisfaction in their creations and were happy to share with those who appreciated their work. In recent years more science educators began to recognize the potential of such simulations in teaching and learning. While interactive simulations cannot replace actual laboratory experience, they could complement laboratory work.

One could begin to exploit such simulations for web learning if they fulfill some meaningful objectives. In some ways I have found the internet-based density simulation an appropriate tool in science teacher education. I have adapted materials from the website http://www.explorescience.com/to conduct a web-learning activity (Appendix I). Pre-service teachers could open the file, conduct a number of hands-on manipulations, record the data and finally respond to various questions that would draw upon their ability to think and to use IT appropriately.

This density simulation together with an appropriate worksheet allows students to build their knowledge relating floating or sinking with the science concepts of density and relative density. This is what Redish (1999) meant when he coined the term "scientific constructivism". A dose of social constructivism can easily be injected by having more than one student working on the task together. Students will need to respond to questions on the relationship of various factors/ variables with an object's ability to float or sink based on the data collected, with some help in re-organizing their data. This simulation could also help address and assess potential alternative conceptions among respondents who are beginning to study this topic. Deep processing/thinking would be required of respondents in using spreadsheet software to display appropriate relationships so as to determine whether there is any pattern in the data collected. To have a better grasp of the respondents' conceptual understanding, they will be asked to explain their initial responses.

Pre-Service Teachers' Performance on Density Simulation

In order to assess and reflect on the use of the internet-based simulation, the internet activity based on the density simulation was administered to a group of first-year pre-service teachers undergoing a two-year programme at the diploma level. Such a cohort may, upon graduation, teach science at the primary level (Grade 1–6). Some selective findings of the performance of this group of pre-service teachers are presented below.

Responses to question "What does the initial 0 ml (0 cm^3) reading of the graduated cylinder indicate?"

This question is consistent with the minds-on approach advocated by Yap (1997), that it is appropriate to think about certain procedural steps in conducting experiments or laboratory work. It appears that a number of respondents associate the initial 0 ml reading to alternative conceptions such as:

(1) volume of liquid in the graduated cylinder

"... no volume of the liquid ..."
"... does not contain any form of liquid"
"... (cylinder) is empty"
"... initial volume of water in the cylinder"
"... initial volume of the water without any object"

(2) accuracy of measurement

"... measurement of the volume of the object is accurate"

A number of respondents could associate this initial 0 ml reading to the context when there were no object in the cylinder. For example, they responded with descriptions like:

"... calibrated to exclude volume of water ..."
"... no object in the cylinder ..."
"... base measurement of volume ..."
"... starting point of volume measurement ..."
"... initial water level of beaker before any object is being placed in ..."
"... reading before object placed inside cylinder ..."

However, none of them made any attempt to relate the initial 0 ml and subsequent readings to the volume readings when the water is displaced by an immersed object. This is how we then obtain a measure of the volume of the object.

Responses to questions on the relationship between mass, volume and density of an object and its ability to float or sink

Since respondents were allowed to discuss with one another it was not difficult to obtain the correct 'answers' in terms of "Yes" or "No" to the questions asking for the relationship between mass, volume and density of an object and its ability to float or sink. However, real understanding is better assessed from their explanations.

The respondents had to rank the data they obtained from their hands-on activity with respect to mass, volume and density. Yet none of them make any attempt to use the data to help them answer these questions. It was apparent that they did not realize the use of such an activity or how it was meant to be of some help.

They may know that one factor that determines whether an object will float or sink is the "density of the object relative to the density of the liquid". However, mere ability to regurgitate this fact does not show meaningful understanding. Such responses include:

"Ability to sink or float depends on density, not mass."
"The mass of an object does not indicate the ability to float and sink ..."

Even when explaining why there is a pattern between the density of an object and its ability to float or sink, almost all responded in a manner similar to:

"Anything with density less than 1 floats."

What is surprising in this activity is the total neglect in using the data from the hands-on exercise to help answer the questions. A few of the respondents did make feeble attempts to use the data in their explanations:

"Bigger mass doesn't mean the object will not be able to float. Example: grey triangle of mass 24g can float, red rectangle of mass 42g can float too."

In a Piagetian sense, such a response will fit thinking at a concrete level. If they were thinking at a higher (or abstract) level, they will respond with examples of objects with smaller masses that will float and sink and also objects with bigger masses that will float and sink.

Responses to question on using the spreadsheet

One common IT tool that is introduced to most students is the use of spreadsheet software, for example, Microsoft Excel. In science teaching and learning such software would be appropriate to investigate the relationship between two variables, for example force and acceleration. Oftentimes, the two variables have continuous values and hence line graphs are used to look at their relationship. For this task, the ability to float or sink is represented only by two discrete category values. Nevertheless, it is still possible to determine whether there is a pattern in the respective data set. Such relationships can be displayed through the Excel table of data or histogram plot. This task certainly requires deep processing with an IT tool.

While the majority of respondents are familiar with the general use of Excel, they were not able to use Excel to display appropriate histogram plots and to interpret from such plots. This indicates a need for more practice and use of such IT tools in a science teaching and learning context.

Concluding Remarks

Internet-based simulations are increasingly prevalent. With improved internet technology, we would have less problems with lack of easy and fast access to such resources even in the classroom. Nevertheless, we need to be able to exploit them in more meaningful ways so as to enhance classroom teaching and learning.

While IT simulations may have their role in science education, it is also timely to remind oneself that they cannot replace the traditional laboratory experience completely. IT simulations may be very useful and meaningful in cases where the practicality and availability of actual laboratory experiences in the schools are not possible. Such an example would be the study of nuclear reactions. However, on the other hand, actual handling and usage of different types of instruments (e.g., vernier caliper, micrometer screw gauge, convex and concave lenses) are still important for science students.

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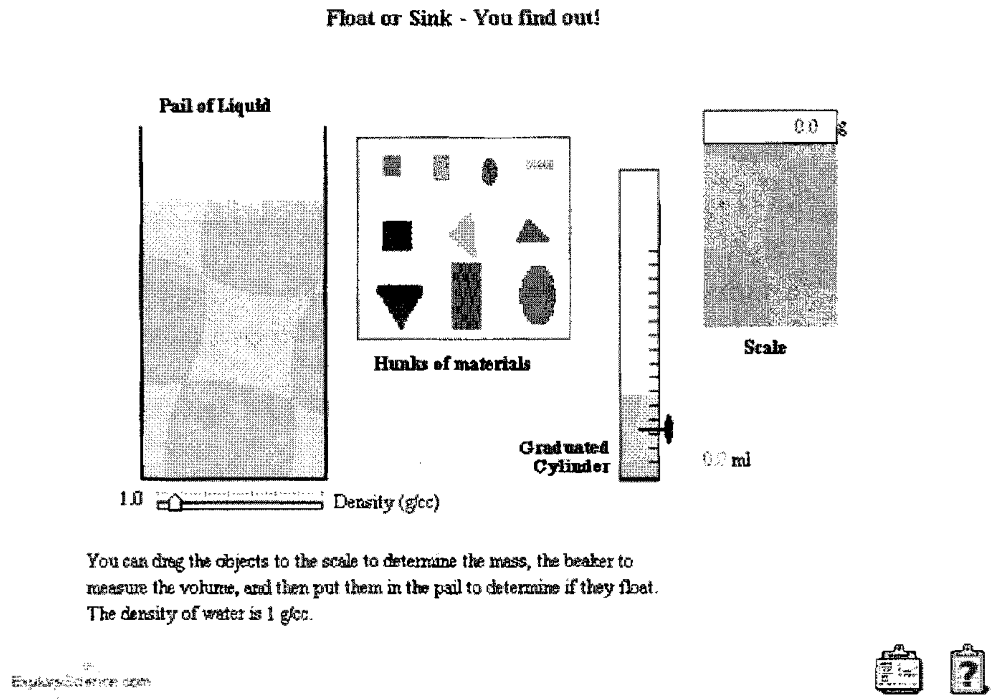
Appendix I

Interactive Hands-on and Minds-on Investigation Using an Internet Resource

(*Virtual Experiment* based on Raman Pfaff ExploreScience at http://www. explorescience.com/activities/Activity_page.cfm?ActivityID=29)



You are going to conduct a virtual laboratory to investigate why certain objects float while others sink.
Before you begin, record your name and that of your partner (if you have one) at the time that this virtual laboratory was conducted.

Student Name (#1):

Student Name (#2):

Set the density scale so that it reads 1.0 g/cm^3.

You can grab an object by holding the left button of the mouse down over it.
You can then drag and drop the object (a) on the big scale to measure the mass of the object, (b) into the graduated cylinder to measure the volume of the object

(note the sophisticated thumb tack that hold things underwater at the time), and (c) into the pail to see if they sink or float.

For each object (identified by colour and shape), measure the mass and volume and then calculate the density (mass/volume). Also determine whether it will float or sink.

Record the results in the table below.

Object Description (Start top left)	Mass (g)	Volume (ml)	Object Density (g/ml)	Does it float?	Rank mass (ascending)	Rank volume (ascending)	Rank density (ascending)
Red Square							
Purple							
Rectangle							
Purple							
Oval							
Orange/Golden							
Rectangle							
Blue Square							
Green Triangle							
Grey Triangle							
Blue Triangle							
Red/Black							
Rectangle							
Red Oval							

Questions

1. What does the initial 0 ml (0 cm^3) reading of the graduated cylinder indicate?

2. Is there a pattern between the mass of an object and the ability of the object to sink or float?

Yes No

Why?

3. Is there a pattern between the volume of an object and the ability of the object to sink or float?

Yes No

Why?

4. Is there a pattern between the density of an object and the ability of the object to sink or float?

Yes No

Why?

5. For questions 2 to 4, can you suggest how you could use a spreadsheet software to help you answer the questions?

6. If the density of the liquid is changed to 3.0 g/ml (3.0 g/cm^3), which column(s) in the table above will be affected?

Why?

Confirm your prediction by carrying out the experiment with the new density value.

(When you are done, click the "Submit" button to send your report to your lecturer!)

Submit Reset