Combining Computer-Simulated Experimentation and Microcomputer-Based Laboratories

Martin Riopel
Universite du Quebec a Montreal
Canada
riopel.martin@uqam.ca

Pierre Nonnon
Universite de Montreal
Canada
pierre.nonnon@umontreal.ca

Gilles Raiche
Universite du Quebec a Montreal
Canada
raiche.gilles@uqam.ca

Abstract: To make science laboratory sessions more instructive, we have developed a learning environment that will allow students enrolled in a mechanics course to be involved in a scientific modelization process by combining computer-simulated experimentation and microcomputer-based laboratories. The most original part of the environment is that it lets the students compare the simulated animation with the real video by superposing the images. Using this software with students lets us observe that they were able to use the software to produce adequate answers to questions concerning both previously taught concepts in physics as well as new theoretical ones. The students completed the experiment about twice as fast as usual and considered that the use of the software had resulted in a better understanding of the phenomenon. We conclude that it would be interesting to further investigate some of the benefits associated with this environment, particularly the acceleration effect and the equilibrium between inductive and deductive reasoning that we observed within this research.

Introduction

Since their appearance in the eighties, microcomputers have become more and more present in our society. They are now clearly an essential part of it and the educational community has to figure out how to make good use of them. Studies on computer-based scientific education generally include four types of applications defined in (Berger *et al.* 1994):

> *computer-assisted instruction (CAI), generally referring to drill or practice and tutorials; computer-managed instruction (CMI), generally referring to computer evaluation of student test performance, guiding students to appropriate instructional resources, and record keeping; computer-simulated experimentation (CSE); and microcomputer-based laboratories (MBL), referring to an interface between a computer and a data-collecting device.* (p. 467)

We also considered important to add to these types a fifth one: computerized adaptive testing (CAT) defined in (Raiche, 2004). In the last years, most of the research carried out at the *Laboratoire de Robotique Pedagogique* of Montreal concerned two types of applications—computer-simulated experimentation and microcomputer-based laboratories–which are well suited for students learning the scientific modelization process. For example, the work of (Fournier 2001) concerned a microcomputer-based laboratory environment that allowed students to construct a measuring system while engaging in an essentially inductive reasoning process. Another example is (Cervera 1998) that entailed a computer-simulated experimentation environment that allowed students to simulate fluids in closed systems in order to visualize and manipulate –in a deductive reasoning process— usually hidden phenomena. We believed that these examples entailing microcomputer-based laboratories and computer-simulated experimentation applications could and should be viewed as complementary ones.

To explore this topic further, we have developed a learning environment that will allow students enrolled in a mechanics course at college or university level to be involved in a scientific modelization process by combining computer-simulated experimentation and microcomputer-based laboratories. Within this computer application, each action could also be automatically recorded and identified while the student is using the software. The most original part of the environment is that it lets students compare the simulated animation with the real video as both images are superposed.

Considerations

In order to guide the development process, we adopted a realist epistemological position as defined in (Alters 1997) and (Bégin 1997). This position proposes the existence of an objective truth that science tries to reveal. We believed that this position was a meaningful way to explain to the students the need for real experimentation in the scientific modelization process. For this reason, we integrated real and simulated experimentation into the same software application. Besides, from an educational perspective, we believed that simulated realities could have more instructional value when combined with reality itself.

We also considered the basic patterns for inductive and deductive reasoning as presented in (Joshua & Dupin 1999) and (Lawson 1994). Our goal was to assist, to facilitate and to record both inductive and deductive reasoning. We took advantage of new possibilities introduced by the combination of computer-simulated experimentation and microcomputer-based laboratories to maximize both the efficiency of the students´ work and the recording of the learning environment.

Finally, we considered the perspective proposed by (DiSessa 1993) concerning the *phenomenological primitives* (p-prims) as regards the building blocks of understanding of the physical world. These p-prims, akin to the primitives of a computer program, react to input parameters. With these p-prims, students put physical parameters in relation to produce explanations. Considering this perspective, we have developed a learning environment which lets students relate as easily and as directly as possible the physical parameters.

Presentation of the prototype

The learning environment has been developed in Visual Basic for Windows. The multi-document interface is based on three types of windows: the animation window (shown in Fig. 1), the graphical window (shown in Fig. 2) and the parameter window (shown in Fig. 3). These three windows are associated to three types of representation of the same phenomenon. Students can choose to show or to hide any of the windows. They can also adjust the display parameters of each one.

We believe that this new approach really facilitates the scientific modelization process making it more real and more fun. With this software, students can obtain answers to specific questions even without the teacher's intervention and theses answers are amazingly accurate. For example, they can produce a movie of a falling ball and determine numerical values for the air friction coefficient, the horizontal wind speed and the restitution coefficient associated with the fall and the collision with the ground.

Figure 1: Examples of animation windows. In the window on the left, the points correspond to the positions of the real falling ball–the one on the right—as measured on the successive images of the video sequence—the ball on the left is a simulated one—. In the window on the right, three types of simulated objects are shown.

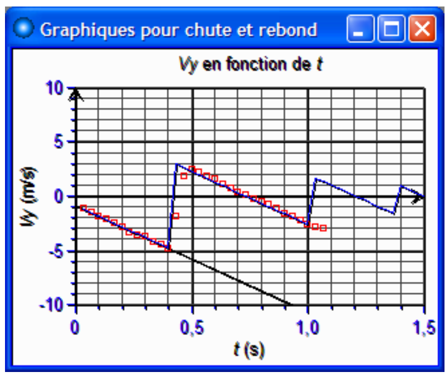

Figure 2: Example of a graphical window for the vertical speed of a bouncing ball as a function of time. The small squares are associated to the measured values. The upper solid line is associated to the simulated values while the lower solid line is associated to the analytical function v_y = -9,8 t.

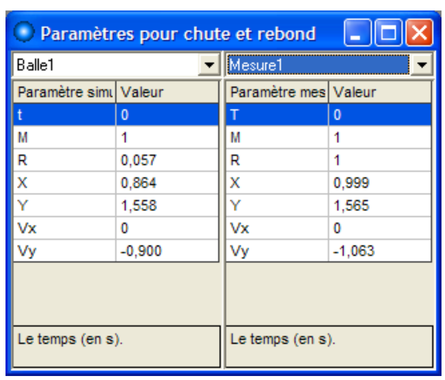

Figure 3: Example of a parameter window for the bouncing ball. Simulated parameters are shown in the left column. Measured parameters are shown in the right column: Values can be compared directly.

Finally, the learning environment can record and identify automatically every action the students does while they use the software. This functionality is important for the research community because the application can record students' full path of reasoning. It's the combination of computer-simulated experimentation and microcomputer-based laboratory that makes it possible for the environment to assist the students both in induction and deduction.

Results

The prototype was first evaluated by physics teachers. They expressed positive satisfaction for 78% of the questions with a quantitative scale. They proposed over 90 minor modifications that were included in the environment before using it with students. The teachers believed that the environment could be useful for most of the laboratory experiments usually done by the students and especially for the free fall experiment.

We used the environment with a first group of students and recorded both their manipulations and their voices. We compared the written transcriptions with the automatic identification made by the environment and concluded that the students were successfully involved in a modelization process that included both inductive and deductive reasoning.

We also used the environment with a second group of 67 students and observed that they were able to use the software to produce adequate answers to a 68% of the questions concerning both previously taught and new theoretical concepts in physics. The students completed the experiment about twice as fast as usual and considered that using the software resulted in a better understanding of the phenomenon. Typical screenshots for inductive and deductive modelization are shown in figures 4 and 5. Finally, the automatic recording and identification made by the learning environment revealed that the students had completed the experiment in an average of 41 min. (56% induction, 44% deduction) or 74 actions (41% induction, 59% deduction).

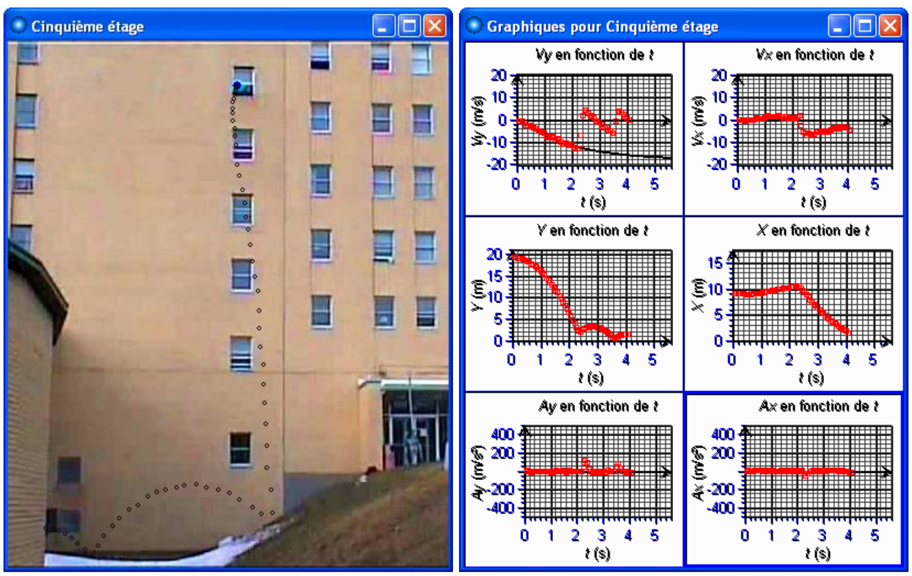

Figure 4: Screenshot for an MBL inductive modelization made by students using the learning environment. The students obtained the measured points in window on the left by clicking on the successive video images of the falling ball. The window on the right displays the graphics for the horizontal and vertical position, speed and acceleration as a function of time.

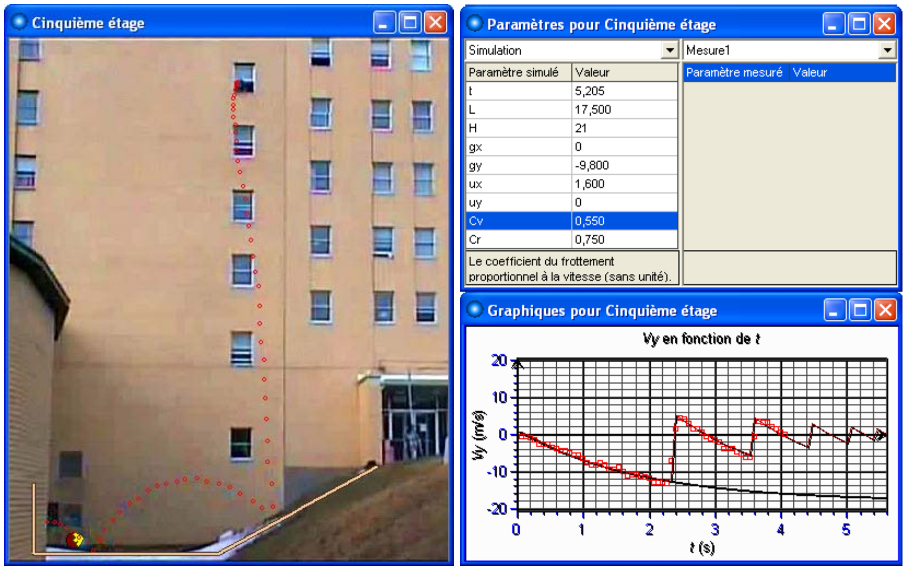

Figure 5: Screenshot for a CSE deductive modelization made by students using the environment. The students created a simulated ball in the window on the left and adjusted the physical parameters to match the movement on the video sequence. With the simulated walls, they were able to match bounces of the ball as shown in the graphic for vertical speed as a function of time on the lower right corner.

When asked to explain their appreciation of the software, students gave some interesting answers. For example: "*we could see for ourselves that air resistance that we usually neglect was not negligible*", "*video is a direct representation of reality, so we could compare directly theory with real life", "It was fun to manipulate real life phenomena".*

Conclusion

To make science laboratory sessions more instructive, we have developed a learning environment combining computer-simulated experimentation and microcomputer-based laboratories. We observed that students were able to use the environment to produce adequate answers to questions concerning both previously taught and new theoretical concepts in physics. We conclude that this use of the computer in science education can broaden the range of possibilities both for learning and teaching as well as it can provide new avenues for researchers who can use it to record and study students' path of reasoning. We also believe that it would be interesting to further investigate some of the benefits associated with this environment, particularly the acceleration effect, the improvement of students' reasoning and the equilibrium between induction and deduction that we observed during this research. Computerized adaptive testing could also benefit from these developments.

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