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# Integrating History of Science in Science Education through Historical Microworlds to Promote Conceptual Change

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This paper proposes a new way to integrate history of science in science education to promote conceptual change by introducing the notion of historical microworld, which is a computer-based interactive learning environment respecting historic conceptions. In this definition, "interactive" means that the user can act upon the virtual environment by changing some parameters to see what ensues. "Environment respecting historic conceptions" means that the "world" has been programmed to respect the conceptions of past scientists or philosophers. Three historical microworlds in the field of mechanics are presented in this article: an Aristotelian microworld respecting Aristotle's conceptions about movement, a Buridanian microworld respecting the theory of impetus and, finally, a Newtonian microworld respecting Galileo's conceptions and Newton's laws of movement.

**KEY WORDS:** conceptual change; history of science; microworld; historical microworld.

## INTRODUCTION

One of the most frequently mentioned problems in science education is the lack of qualitative or conceptual understanding about natural phenomena. Students are often able to solve relatively complex scientific problems with algorithms based on a blind application of mathematical equations (Gabel *et al.*, 1984; Nakhleh and Mitchell, 1993; Lin *et al.*, 2002), yet they are unable to answer correctly to simple qualitative questions. This problem has prompted researchers to make efforts to identify students' conceptions which are not coherent with scientific conceptions (Wandersee *et al.*, 1994; Confrey, 1990; Liu, 2001; Sequeria and Leite, 1991; Driver and Easley, 1978; Viennot, 1979) and to propose models to understand the nature of conceptual change that occurs when a student improves his conceptions (Posner *et al.*, 1982; Vosniadou, 1994; diSessa, 1993).

Among the solutions proposed to promote conceptual change, many researchers in science education, before and since Matthews (1994), have studied the crucial role of history and philosophy of science (HPS) in science education, especially with the intention to improve science literacy and the qualitative understanding of scientific concepts. Addressing the question of how to integrate history of science in science teaching, Wandersee (1990, 1992; Wandersee and Roach, 1998) proposes the use of *historical vignettes* which are short stories about conflicting events in a scientist's life related to the course's subject, told with the aim to bring students to think about the nature of science. Matthews (1998, 2000, 2001a, 2001b) suggests the use of *historical case studies*, like the case of the movement of a pendulum. Arons (1989, 1991) recommends using a *story line approach*, which consists in telling the story of the evolution of a concept in chronological order.

Another solution proposed by researchers to promote conceptual change concerns the use of *microworlds*. As we explain later on, these are (typically computer-based) environments designed to allow student interaction in a specific, limited realm. As Roth (1996) points out, students' conceptions "are

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thought to be part of conceptual frameworks which students construct as a result of their interaction with the world'' (p. 171). Using a controlled, restricted microworld may thus help students focus on aspects of phenomena abstracted from the ''real world'' and therefore increase the possibility of ''[abandoning] their misconceptions and [adopting] the cognitive structure held by [scientists]'' (Roth, 1996, p. 171). The use of microworlds resulting in conceptual change has been documented by many researchers from Papert (1980) and diSessa (1986) to Legendre (1995, 1997) and Potvin (2002).

This paper aims to propose an alternative solution to the problem of conceptual change by introducing the notion of *historical microworlds* (Masson, 2005), which try to take advantage of the synergy of using both history of science and microworlds in science education. Historical microworlds are computer-based interactive learning environments developed not only to help students understand scientific conceptions of the past, but also to understand the weaknesses of their own conceptions. After outlining the theoretical background and defining the notion of historical microworld, we present three examples based on the history of mechanics: an Aristotelian microworld, a Buridanian microworld and, finally, a Newtonian microworld.

## THEORETICAL BACKGROUND TO THE NOTION OF HISTORICAL MICROWORLDS

In this section, we first examine why researchers think that integrating history of science in science education may help to promote student's conceptual change and, secondly, we explain why we think that using microworlds is a promising way to integrate history of science in science education.

### History of Science to Promote Conceptual Change

Different reasons to integrate history of science in science teaching are reported in science education papers. Many researchers argue that knowledge of history of science is essential to develop an understanding of the nature of science and, therefore, a more complete science literacy. Others examine the role of history of science to promote conceptual change in science learning. Historical microworlds are based on this latter.

The arguments supporting why history of science might promote conceptual change are based on two ideas: (1) the similarity between students' conceptions and past scientists' or philosophers' conceptions and (2) the parallelism between the development of children's understanding and the evolution of scientific concepts in history of science.

The first point is easy to agree on: there is a strong relation between students' conceptions and historic conceptions (this is, conceptions held by scientists at some time in history) reported in empirical studies. Indeed, one of the most important results of research studies on students' conceptions is that they look like historic ones (Wandersee *et al.*, 1994). This is particularly well documented in the field of mechanics (Matthews, 1990); for the examples we develop later on this paper, the study of Sequeria and Leite (1991) is of special interest as they compared systematically students' conceptions about force and movements with historic conceptions and found a strong similarity.

The second point needs to be discussed more critically: there is not a perfect parallel between the development of students' understanding and the evolution of scientific ideas, but the similarity is important enough to accept the arguments based on it. According to Monk and Osborne (1997), the question of the parallelism between students' conceptions and historic conceptions is recurrent in the constructivist literature and, although many researchers have remarked significant correspondences, there are no proofs based on detailed studies that students' conceptions recapitulate historic conceptions. In the same way, Sequeria and Leite (1991) agree with Monk and Osborne (1997): there are significant resemblances between the evolution of students' conceptions and the evolution of scientific ideas, but there are some differences too.

One of the main causes of the differences between an individual's conceptual evolution and the historic evolution of knowledge might be the significant differences between the contexts of production of both students' conceptions and past scientists' conceptions (Monk and Osborne, 1997). Metaphysical, epistemological and also sociological factors might play an important role in the construction of knowledge. Because students live in a completely different world than the one of scientists living a long time ago, it is not surprising to find important differences between both constructions.

Nersessian (1991) also agrees with this point of view. She argues that the recapitulation cannot be identical, because historic conceptions come not only from empirical experience, but also from metaphysical, epistemological and sociological factors. However, she also contends that, even though the recapitulation is not identical, it is plausible to think that a more limited recapitulation can be found; and in fact, that the more the content is related to familiar experiences for students, the more the recapitulations will be similar. The motion of objects on earth is an example of that kind. However, when metaphysical, epistemological and sociological factors are more connected to the development of scientific ideas, the recapitulation can be nothing else than limited.

Despite these limitations, some researchers believe that the integration of history of science in science teaching can promote conceptual change. Discussions about historic conceptions certainly allow students to make explicit and think about their own conceptions (Monk and Osborne, 1997; Lin *et al.*, 2002). Moreover, being in contact with historic conceptions may help students to realize the weaknesses or problems of their own conceptions (Wandersee *et al.*, 1994; Confrey, 1990). Teaching based on the history of science becomes especially interesting to promote conceptual change when students' conceptions are conflicting with scientific conceptions for the same reasons that the scientists of the past did. As well, discussions on historic conceptions have the advantage to show students a sequence of evolution of their own conceptions toward actual scientific conceptions (Confrey, 1990). This also allows for comparing different conceptions (conceptions from both students and history of science) and to understand their advantages and disadvantages in specific contexts by exposing the differences between ways to think before and after (Monk and Osborne, 1997). Moreover, in following a historic sequence, conceptions often change from simpler to more complex, from more intuitive to more abstract. Finally, by teaching science using history of science, we teach more qualitatively and we focus less on solving numeric problems and more on understanding concepts.

## Using Microworlds to Integrate History of Science in Science Education

The notion of *microworlds* is relatively recent. It was introduced by Papert (1980) to describe stimulating designed environments in which students may interact to learn specific concepts and develop their intellectual structures. An *artificial microworld* is more specifically related to the use of the computer to elaborate and deliver such interactive environment (diSessa, 1986; Legendre, 1995).

One of the most significant aspects of the notion of a microworld is that it simulates a *simplified* version of the real world (White, 1992). In this, it shares with simulations the advantages of providing "the ability to ask probing 'what-if' questions" (Horwitz and Barowy, 1994). Moreover, microworlds offer the possibility, as some simulations do, of confronting students "with an ensemble of related experiences that [they] themselves come to see as conflicting with their own ideas," a condition deemed necessary for conceptual change (Richards *et al.*, 1992, p. 69).

As a simplification, being able to determine the complexity level of the microworld is of prime importance for science education:

> [T]he great advantage of using a microworld is that it can comprise a particular range of phenomena not always possible or convenient to isolate in the "real" world. It is a *micro*world, much smaller than the real world, with substantial constraints by virtue of its programming and interface on the number of causal factors and on the possible actions students might take. (Metz and Hammer, 1993, p. 55)

For example, in the field of mechanics, a computer-based microworld may neglect factors such as air resistance or friction to help students learn Newton's first law, or may constrain an object to move in a one-dimensional space to help students learn about collisions of two objects. Many researchers have studied the use of microworlds in mechanics education (Papert, 1980; diSessa, 1982, 1986; White, 1992, 1998; White and Horwitz, 1988, Legendre, 1995, 1997; Potvin, 2002; Roth, 1996). Inspired by Snir *et al.* (1993) and by Richards *et al.* (1992), Härtel (2000, p. 276) believes that computer simulations can be "a tool to support the modification of prescientific concepts, to acquire and understand new concepts." He also argues that simulation programs can encourage both a more qualitative approach by stopping the dependence on quantitative mathematical methods, and a more interactive approach by allowing the student to test hypothesis rapidly and receive immediate feed back.

We propose in this article to integrate history of science to promote conceptual change by using microworlds. Integrating history of science in science teaching means presenting historic conceptions and their weaknesses, but also, and especially, comparing historic conceptions with today's conceptions in order to understand how conceptions have progressed, often from simple and intuitive formulations to more complex and abstract formulations. Because microworlds present a simplified version of the real world, it is possible to elaborate a sequence of microworlds, from the relatively simple and intuitive Aristotle's conceptions to the more complex and abstract Newton's laws of movement. By combining history of science and microworlds, we hope to help students to promote conceptual change.

For us, in the notion of historical microworld, the word ***microworld*** refers to a *computer-based interactive learning environment*. Interactive, because students can observe the effects produced when they change some parameters such as the mass of the moving object, the initial velocity and even the power of the gravitational field or the importance of the air resistance for falling objects. A microworld is not just a video or a book where students read and listen to learn. It is a virtual world where they may test hypotheses by modifying some factors involved in the microworld and by observing what happens with such and such mass, gravity or whatever you can modify in the interactive virtual world.

The microworld is said ***historical*** because *it presents historic conceptions*. "Presenting" does not mean to show historic conceptions by telling the date, the name of a scientist and a resume of his theory. It rather means that the microworld in which the learner may interact is a world programmed to respect historic conceptions that we want to present. Concretely, it means that the programmer has selected and designed the objects, the variables that the learner will be able to modify, and the environment of interactions (gravity, air resistance, etc.) with the aim of creating an "incubator" (Papert, 1980) where students will learn about the historic conceptions we chose to present. Next section will give examples of how we programmed a virtual world to be an historical microworld.

## THREE EXAMPLES OF HISTORICAL MICROWORLDS IN MECHANICS

The historical microworlds presented in this paper have been elaborated with the simulation software *Interactive Physics$^{TM}$ 3.0*. In many ways, its interface looks like a drawing software. You can create objects such as a circle or a square and put any colors you want. However, behind this user-friendly interface is hidden a powerful calculator. In fact, the objects created on the screen are placed in an environment which rigorously respects Newton's law of movement. In that software, all drawings (circle, square and others) are considered objects with properties that can be defined such as mass, elasticity, friction coefficient, etc. These objects are placed in an environment in which the user may control almost all variables (air resistance, gravity, etc.). When you start a simulation with a circle under the terrestrial gravity field, you can see the ball falling as if the real experiment had been done.

We present here three historical microworlds in the field of mechanics made with *Interative Physics$^{TM}$*. The Aristotelian microworld is composed of two situations. The first presents a box that moves horizontally and the second, a balls falling in the air. The Buridanian microworld presents an arrow propelled by a bow. And finally, the Newtonian microworld is also composed of two situations: a ball rolling down an inclined plane and a ball falling from the top of a navigating ship.

### Aristotelian Microworld

Although *Interactive Physics$^{TM}$* is based on Newtonian physics, the designer of the microworld may choose to program the world in order to respect Aristotle's conceptions of movement by controlling gravity, air resistance and friction between objects and by limiting the variability of the parameters that the user can modify. This is what we did when we constructed both situations of the Aristotelian microworld. Whatever the students choose for initial velocity, applied force or mass, the movement will respect all of Aristotle's conceptions of movement.

#### *A Box Sliding on the Floor*

Situation 1 presents a rectangular box sliding on the floor (Figure 1). The vertical lines are simply painted on the back wall and do not interact or collide with the box. Above the box, there are three controllers. From left to right, there are the initial velocity oriented toward the right (varying between 0 and 50 m/s), the force applied on the box toward the right (varying between 0 and 10 N) and, finally, the mass of the box (varying between 1 and 3 kg). At the left of the controllers, there is the start button (to make the box moves) and the reinitializing button (to change controllers and make another try). At the right, there are two indicators: the time, starting when you push the start button, and the box's speed, always toward the right. The environment has been

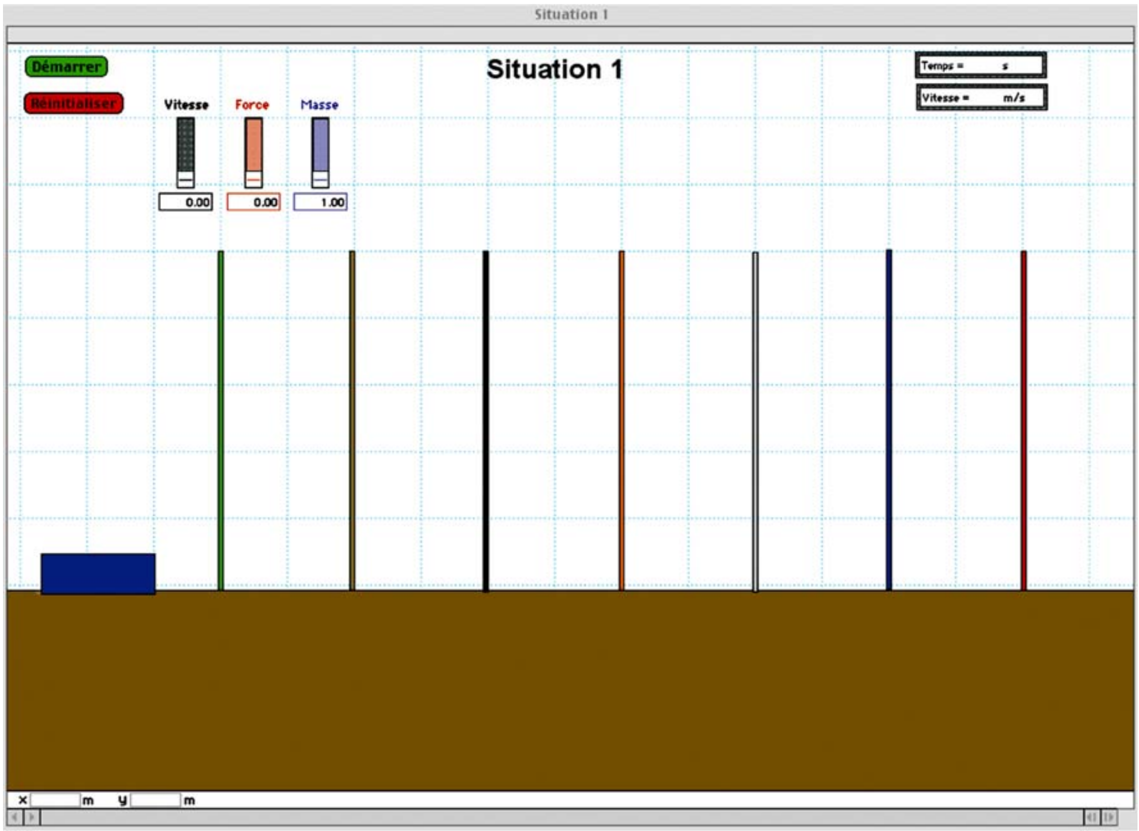


**Fig. 1.** First situation of the Aristotelian microworld: a box sliding on the floor.

programmed with a terrestrial gravity of 9.8 m/s$^2$ and a standard air resistance ($F = k$*velocity*cross-section, where $k = 5.0$ kg/m*s). The friction coefficients are 0.3 for both the box and the floor.

Because controllers have been limited to certain values and because of the choice of gravity, air resistance and friction, this first situation will respect Aristotelian mechanics whatever the values chosen by the user for velocity, force and mass. If the user selects an initial velocity of 0 m/s and a force of 0 N, the box will not move. But, if the user changes the initial velocity to something else than zero, for example 10 m/s, the box will move toward the right with a decreasing speed from 10 m/s to 0 m/s because of air resistance and friction. According to *Aristotle's principle of rest*, all moving objects are pushed by something or they will slow down and stop (Aristotle, 2002, p. 355; Dugas, 1950, p. 21). Remark that this principle is drastically opposed to the Newton's principle of inertia. If a student using the microworld changes the initial velocity, he will realize that, according to Aristotelian mechanics, the box slows down and stops. If the initial velocity is higher, the box will slide longer but it eventually stops. So, the user, by testing what initial velocity is necessary to move the box until for example the fourth vertical line, is experiencing Aristotle's principle of rest.

When the user begins to change the mass and the force applied on the box, he learns about another Aristotle's principle of movement, the *fundamental principle of movement*.

> [I]f A is the motor, B the moving object, the distance made Γ, the time Δ, then in an equal time, the power A will move half B in the double of Γ, and will move on Γ in a half of Δ. (Free translation of Aristotle, 2002, p. 378)

Translated in mathematical notations, we obtain

$$A \propto B\frac{\Gamma}{\Delta} \tag{1}$$

Or, in more contemporary symbols,

$$F \propto m\frac{\Delta s}{\Delta t} = mv \tag{2}$$

In other terms, Aristotle's fundamental principle states that the higher the applied force is, the higher the object's speed will be. Also, the higher the mass of the moving object is, the lower the speed will be for a particular applied force. For example, the user of the microworld can change the speed of the box by changing the force controller or the mass controller. To speed up the box, the user must set the force higher or the mass lower.

*Two Balls Falling*

In situation 2 (Figure 2), two balls are released when the start button is pushed. The gravity is terrestrial, with 9.8 m/s$^2$, and the air resistance is more considerable than in the previous situation, with $k$ = 10.0 kg/m*s. Horizontal lines are still painted on the back wall and do not interact with ball movement. Modifying the two controllers at left and right can change the mass of both balls. The balls' densities are constant: so, when you set the mass higher, the ball becomes bigger. The mass of the balls can vary between 0.2 and 1.5 kg. Also, under each controller, there is a speed indicator for each ball.

In situation 1, we presented what Aristotle names "violent movement", which is the movement caused by an applied force. It respects Aristotle's fundamental principle of movement and the principle of rest. In situation 2, we present a different kind of movement: the "natural movement". According to Aristotle, this movement can be defined as the spontaneous movement of an object toward its natural place. For example, a rock falls toward the earth because it is its natural place to be there. The heavier an object is, the faster it will fall on the earth (Dugas, 1950, p. 20). This is the Aristotelian *principle of natural movement*.

Situation 2 is designed to respect this principle. Because the mass of the ball cannot be higher than 1.5 kg, the air resistance is very important relative to the gravitational force. Since air resistance increases with speed, it becomes equal to the gravitational force rapidly, so the ball falls at constant velocity. If the mass could be bigger, the ball would accelerate dur-

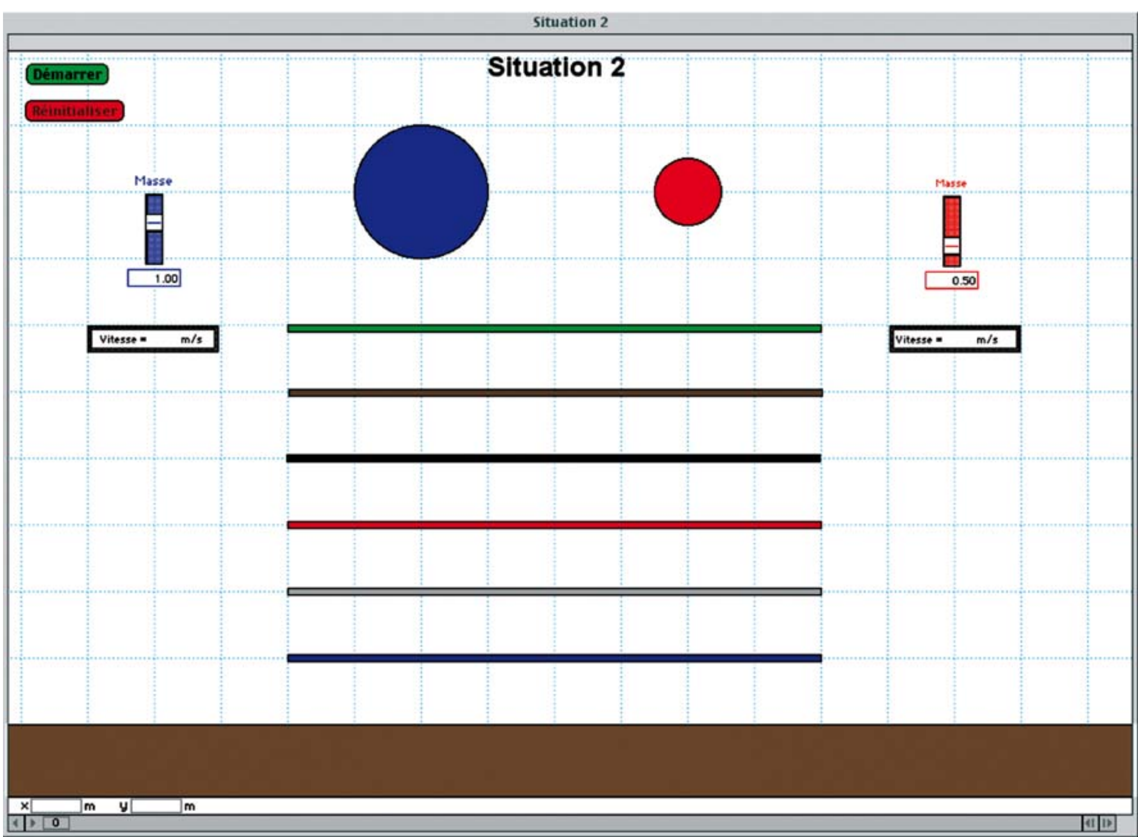


**Fig. 2.** Second situation of the Aristotelian microworld: two balls falling.

ing the fall. But the microworld has been configured to be Aristotelian: an object falls at constant velocity and the heavier the object is, the faster it falls. So, when students want to make the ball goes faster, they have to increase the mass. When they want the left ball falling faster than the right one, they have to give the left ball a greater mass.

### Buridanian Microworld

The third situation shows an arrow suspended in the air (Figure 3). Contrary to the first two situations, vertical lines can interact and collide with the arrow, which will fall between two lines as if they were walls. The arrow cannot pass through or pick on the wall. There are two controllers above the arrow: the left one to select the arrow's initial velocity (as if the arrow were propelled more or less rapidly) and the right one to change the arrow's mass. Initial velocity varies from 10 to 50 m/s and the mass, from 0.1 to 3.0 kg. Still, the gravitational force is 9.8 $m/s^2$, but the air resistance is lower, this time, with $k = 1.0$ kg/m*s. Combining this low $k$ with a cross-section quite smaller for the arrow than for the box of situations 1 and 2, we obtain a microworld where air resistance is really less significant than previously.

According to Aristotle's principle of rest, all objects in an "unnatural" (i.e., violent) movement will stop. So, why does the arrow go so far? Why doesn't it stop? How to explain the continuity of the movement of an arrow? Always according to Aristotle, there must be something that pushes the arrow, because all moving objects are moved by something. For this reason, Aristotle believed that the air pushes behind the arrow, so it continues its movement (Gingras *et al.*, 1998, pp. 69–70).

Except for Philopon in the sixth century, this explanation of Aristotle had not really been criticized until the Middle Ages, when Buridan proposed his *theory of impetus*. Maybe because new technology was emerging at this moment, Buridan does not accept that the air pushes the arrow. According to Goulard (2000) and Rosmorduc (1979, p. 69), he formulates a criticism that includes several examples revealing some contradictions regarding the "air explanation." Buridan notes that a wheel keeps

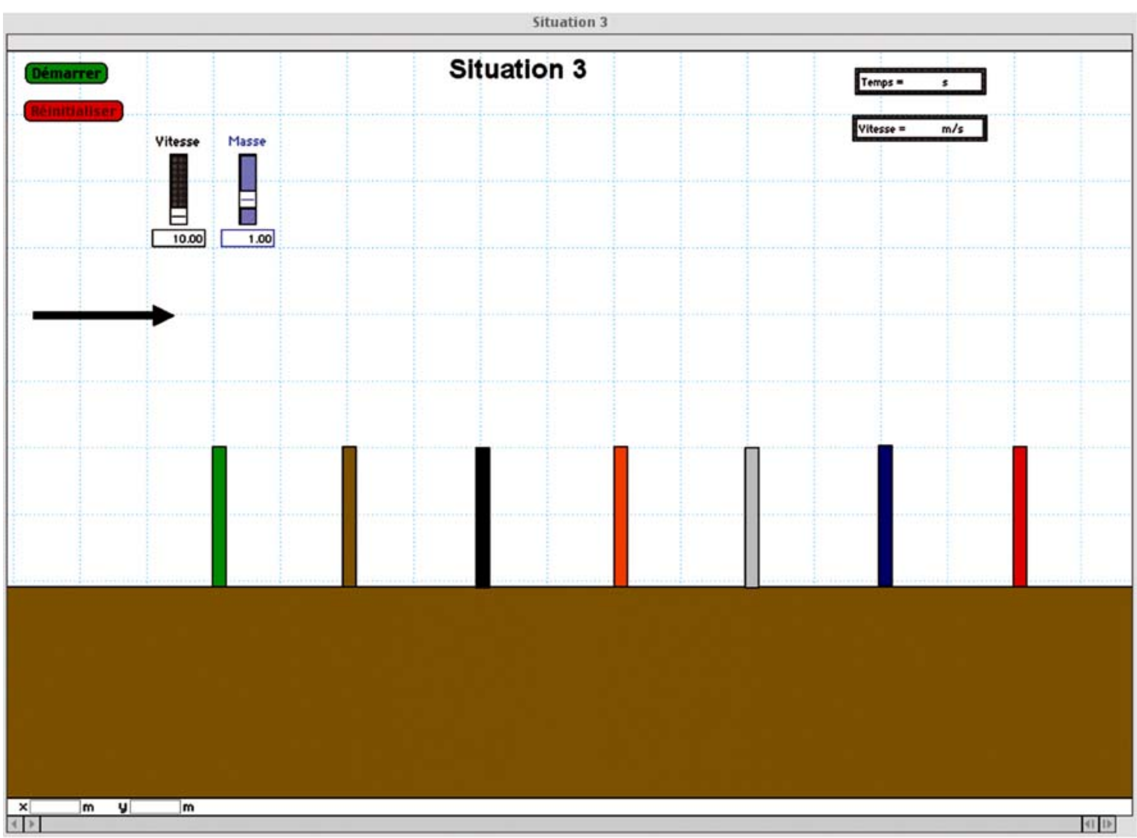


**Fig. 3.** Buridanian microworld: an arrow propelled in the air.

turning even if air cannot push behind it, and the same happens with a top and the blacksmith's forging-wheel. Moreover, why can't the arrow with different shapes at the back (where the air should be pushing) fly faster or slower? For all these reasons, Buridan cannot believe in Aristotle's explanation, so he proposes a new way to think about movement: the theory of impetus. According to this theory, an arrow continues its movement, not because the air pushes behind, but because, when we launch the projectile, it stores some energy that is called impetus. The more we propel the arrow with power, the more it accumulates impetus and will go farther. Because of the air resistance, impetus stored in the arrow fades, so it falls.

The Buridanian microworld (situation 3) is an intermediate between the Aristotelian microworld (where friction and air resistance are so important that all objects in movement stop and all falling objects go at a constant velocity) and the Newtonian microworld (where objects are not stopping, and objects falling or being pushed accelerate). In this Buridanian microworld, students try to put the arrow between two walls by adjusting initial velocity and mass. They cannot use the principle of rest, because the arrow does not stop in the air like the box on the floor. Therefore, students must think about the role of initial velocity on the movement of the arrow. It brings students to deal with the notion of impetus.

## Newtonian Microworld

The next two situations compose the Newtonian microworld. The first (situation 4) presents a ball rolling on different inclined planes. The second (situation 5) shows a ball released from the top of a moving ship. These situations have been programmed with no air resistance and no friction. Because of that, no energy is lost and the object will conserve its movement indefinitely if no force is acting upon it.

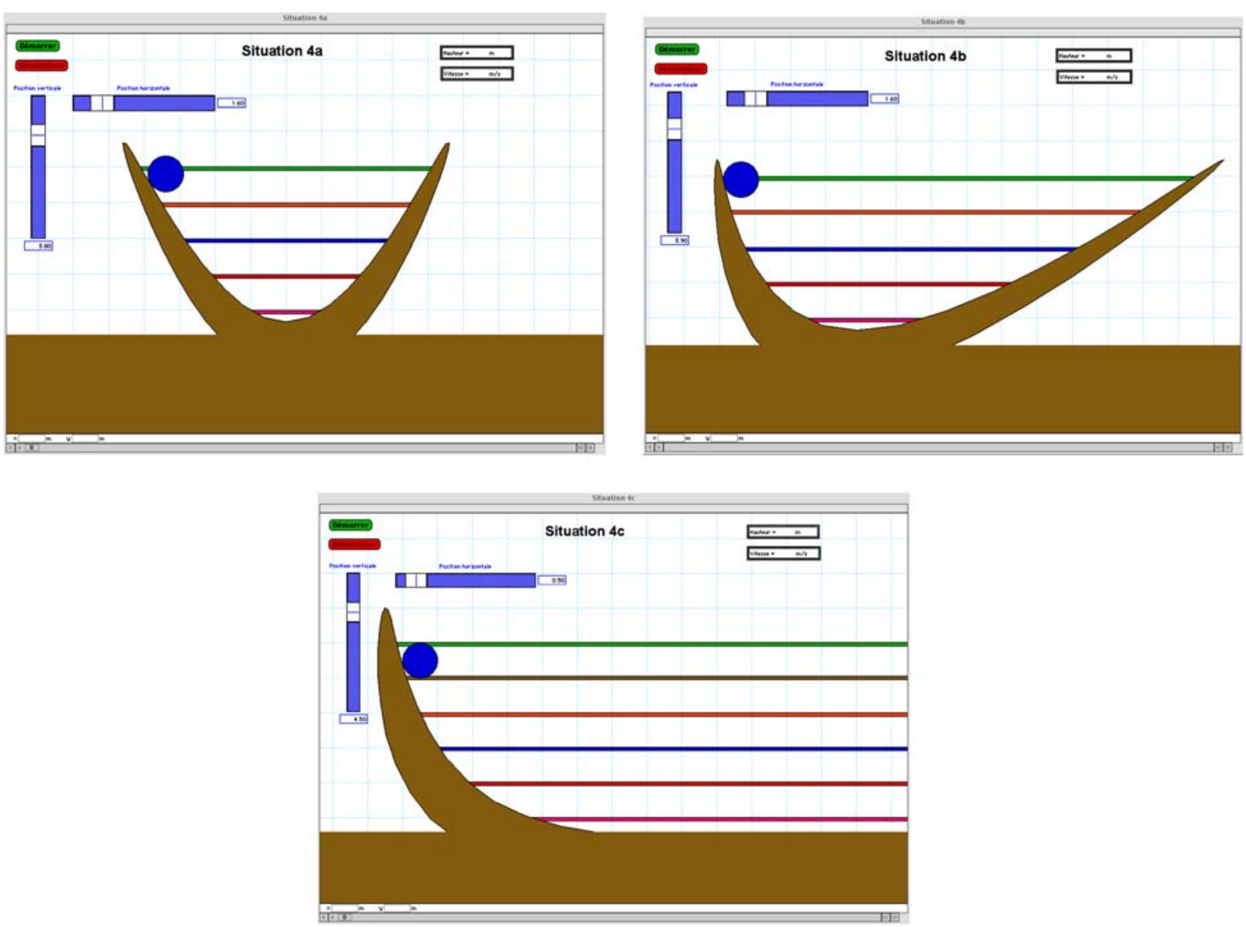


**Fig. 4.** First situation of the Newtonian microworld: a ball rolling on inclined planes.

This respects Newton's first law of movement, also named the *principle of inertia*.

*A Ball Rolling on Inclined Planes*

In situation 4 (Figure 4), a ball located at the top left of an inclined plane rolls down from the left part of the inclined plane and rolls up to the right part when the situation is started; it allows the users to see the effects of the initial position on the ball's movement. Horizontal lines cannot interact with the ball. Users can control the initial position of the ball by using two controllers, one for the vertical position and another for the horizontal position. Situation 4 is composed of three different inclined planes named 4a, 4b and 4c. The first plane is symmetrical: its left and right parts have the same grade. Second and third planes are asymmetrical. The right part of plane 4b has a lower grade than the left, and the right part of plane 4c is horizontal. Note that all left parts of the three inclined planes are identical. The gravity is still a terrestrial 9.8 $m/s^2$, but the situation has been programmed with neither air resistance nor friction.

Because there is neither air resistance nor friction, the ball in situation 4a will not stop at the bottom of the inclined plane. It will oscillate continuously and indefinitely from its initial position at left to the same height at right. In situation 4b, it is all the same, except that the right part of the plane is longer with a lower grade so it will take a longer time to reach the initial height at the inclined plane's right part. Situation 4c is different because the ball cannot reach the initial height at right. Indeed, the right part of the inclined plane is horizontal, so the ball cannot roll at right up to the initial vertical position and the ball will roll indefinitely on the horizontal floor, which respects the principle of inertia. Note that the use of inclined planes to introduce the principle of inertia had been previously employed by Galileo.

*A Ball Released from the Top of a Navigating Ship*

Situation 5 presents a ball released from the top of a ship (Figure 5). Vertical lines interact with the ball in the same way than in situation 3, so the ball can be pitched between two little walls (vertical lines).

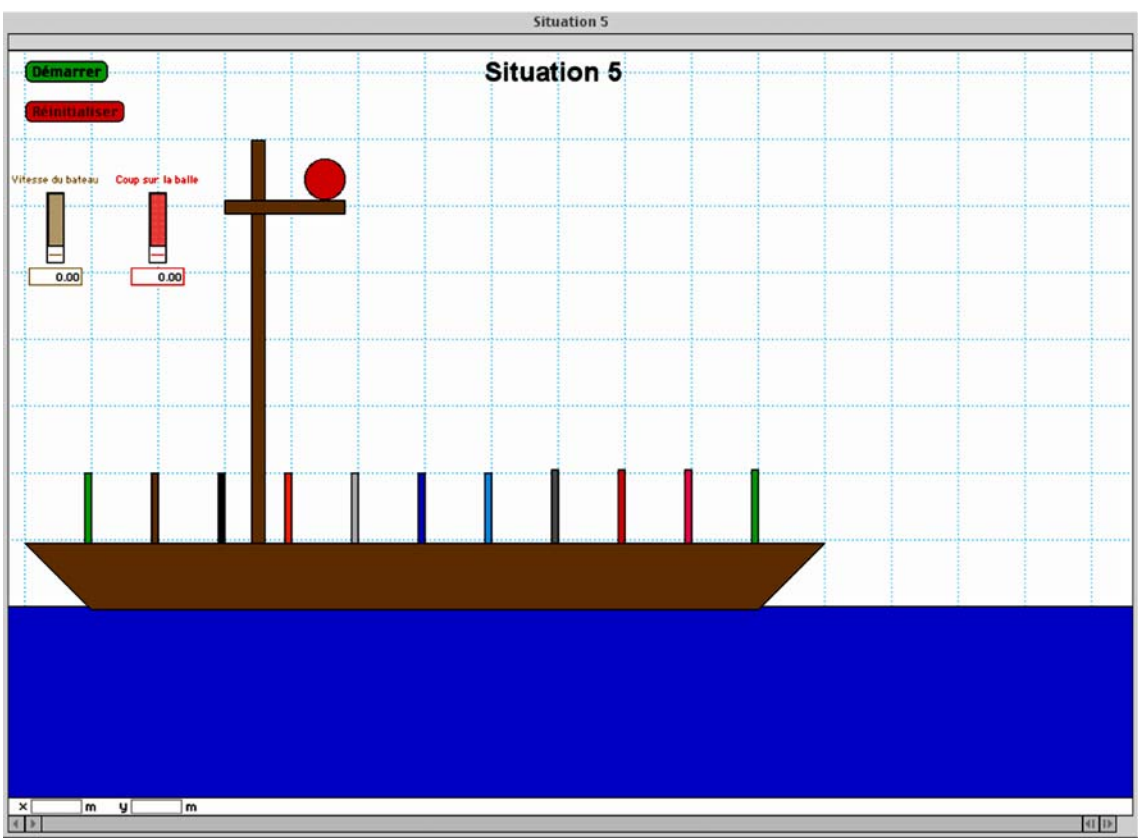


**Fig. 5.** Second situation of the Newtonian microworld: a ball released from the top of a navigating ship.

Users may explore this situation by using two controllers. The first changes the ship's speed, which can vary from 0 to 10 m/s. The second kicks the ball toward the right to obtain an initial velocity of 0 to 10 m/s. As in situation 4, the gravity is terrestrial and there is neither air resistance nor friction.

Users in situation 5 try to put the ball between the walls on the floor of the boat. When the speed of the boat is 0 m/s, users must use the control of the kick to put the ball where they want to. To make the ball fall farther, the kick must be higher. Because there is no air resistance, the speed of the boat does not affect the fall of the ball. Indeed, if the boat's speed is $x$ m/s, than the initial horizontal velocity of the ball will also be $x$ m/s and, because of the principle of inertia, horizontal velocity of the ball will always be $x$ m/s. Consequently, if there is no kick on the ball, the ball will fall just under the place where we released it relatively to the ship. It is interesting to realize that the ball cannot fall between the walls which are at the left of the initial horizontal position, same with greater boat speeds, because there is no air resistance to make the horizontal velocity to decrease. Note that the use of the navigating ship to introduce the principle of inertia had also been previously employed by Galileo.

### *Revisiting Aristotelian and Buridanian microworlds with a Newtonian Twist*

It can be interesting for users to revisit the first three situations and to change some parameters of the virtual environment to transform it into a Newtonian microworld. In situation 1 (a box sliding on the floor), if we take out air resistance and friction, the box with an initial velocity greater than zero will never stop, respecting the principle of inertia. If we pushed the box continuously it will accelerate, respecting Newton's second law of movement. In situation 2, if we remove the air resistance, all balls (independently of the mass) will fall with the same constant acceleration. In situation 3, if we remove gravity and air resistance, the arrow will continue indefinitely in the same direction at the same speed.

## Proof of Concept

As stated before, our main objective in this article was to discuss the bases supporting the use of historical microworlds with the aim to promote conceptual change, and to explain via an example a way to develop microworlds integrating history of science. Logically, larger questions arise, which are beyond the scope of this article, mainly pertaining to the usability and evaluation of such historical microworlds. Are the examples offered in this article directly usable by what kind of learners? Is the approach applicable to other areas of science learning? What does which kind of learner get out of using such historical microworlds in what field of science? Can learners profit from this approach to develop their own historical microworlds, and what would they get out of doing it?

The proof of concept would not have been complete, though, without trying it with some students. As an example, six grade-5 elementary students were asked to participate in individual sessions (a total of five hours in average with each child) with one of the authors. The researcher presented the five environments in sequence and conducted a conversation with each student, leading them to propose what to do and discuss what happened. While the researcher controlled the material interaction with the program, the simulation was responding at all times to student-proposed input. The results where totally satisfactory in terms of the microworlds usability in this mode.

## CONCLUSION

In this paper, we propose a way to integrate history of science in science teaching by using historical microworlds. Because of evidence from science education research that history of science and the use of microworlds might contribute to the understanding of scientific concepts, we believe that combining both history and microworlds by using historical microworlds might contribute to promote conceptual change in science education. The integration shown is a relatively straightforward one in mechanics, taking advantage of the fact that a simulation environment that normally constitutes a Newtonian microworld (this is, that it integrates Newtonian mechanics) can be modified to constitute a Buridanian or an Aristotelian microworld. Basically, the Newtonian microworld is built so that there is no friction or air resistance, and forces produce acceleration modulated by the mass of the object. When friction and air resistance are made significantly big, forces seem to produce speed (this is, speed seems to be proportional to the force applied) and, in the case of free fall, speed seems to depend on the falling object's mass. In particular, an object moving horizontally in the air seems to start with a speed that gradually dies out to let the object fall. The fact that Aristotelian and Buridanian microworlds could be explained as "partial views" on particular examples of Newtonian microworlds (they are not necessarily wrong, just limited interpretations based on unbeknownst or non acknowledged parameters) contributes, in our opinion, to the potential of the set for promoting conceptual change.

Next step is to observe students interacting with the microworlds in order to ascertain what are the effects of this interaction on the process of conceptual change. As well, an interesting question arising is to examine how this notion of historical microworlds can be transferred to others fields such as electromagnetism or physical chemistry.

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