DESIGN OF A TEACHING-LEARNING SEQUENCE TO FACILITATE TRANSITION BETWEEN QUALITATIVE AND QUANTITATIVE REASONING ABOUT KINEMATICS PHENOMENA

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Abstract : Science experiments offered to the pupils in physics classrooms generally do not take into account their alternative conceptions in relation to physical phenomena so that they can encounter difficulties in identifying pertinent factors and expressing it in the form of quantitative equations (Ploetzner & Spada, 1998). Our research aims to specify the transition process between an understanding of an intuitive nature of the properties of phenomena, centered on the qualitative reasoning, and a more definite understanding, centered on the quantitative reasoning such as it is used in problem solving. To favour the understanding of physical phenomena, qualitative as well as quantitative reasoning must be mobilized and used in pedagogic contexts allowing exchanges between the pupils and favouring interaction with phenomena (Trudel, 2005). When combined with activities of exploration of physical phenomena, the resulting approach used feedbacks from the results of manipulations to limit the number of issued hypotheses, which is a prerequisite to their practical verification (Gunstone & Mitchell, 1998; Trudel, 2005). Moreover, the use of software, making easier the collection of data and their organization in form of tables and graphs, allowed the pupils to test their hypotheses much faster than with the traditional laboratory equipment so that pupils can change progressively the parameters of physical situations studied to explore relations between the physical variables (Riopel, 2005). As a conclusion, we draw the limits of the study and offer suggestions to teachers to improve the integration of qualitative and quantitative reasoning in the physics classrooms.

Keywords : Computer-assisted laboratory, kinematic, qualitative reasoning, model, understanding, problem-solving

Introduction

In response to what some have called traditional science teaching, consisting of lectures, exercises, and laboratories, Anderson (2002) recommends that pupils take a more active role in developing their knowledge under the supervision of the teacher. In this approach, called guided discovery, learning results from activities of testing pupils' ideas about the phenomena of their environment. By studying a phenomenon, the pupil is led to identify its properties, propose hypotheses to explain them and develop an experimental protocol to verify them. In doing so, he develops a better understanding of the scientific concepts and methods used by scientists to study the natural world (Llelewyn 2002, Someren & Tabbers 1998).

According to de Jong and van Jooligen (1998), pupils have difficulties in the various phases of the experimental process: hypothesis generation, experimental protocol design, data interpretation and the regulation of the experiment itself. Since these phases, although distinct, are interrelated, these difficulties can only be solved by teaching methods that take into account the cyclical and iterative nature of this approach (Acher & al., 2007, Llelewyn, 2002, Toplis, 2007). Thus, the formulation of hypotheses depends on the interaction between, on the one hand, the pupil's ideas about the phenomena studied and, on the other hand, the characteristics of the phenomena themselves (Trudel, 2005). Among the physical phenomena studied in high school, the learning of motion phenomena, or kinematics, is important for pupils for several reasons: 1) mastery of kinematic concepts is a prerequisite for learning subsequent physical concepts; 2) in kinematics, the pupil learns new methods, such as the construction of Cartesian graphs, the systematic measurement and collection of data, problem solving, etc., which will be useful in more advanced physics courses.

However, if there is one area that causes many difficulties for pupils, it is kinematics, defined as the study of the motion of objects without worrying about its causes (Champagne, Gunstone & Klopfer, 1985, Arons, 1990). There are several reasons advanced by researchers. First, before entering in physics classes, pupils have a wealth of experience about the properties of the motion acquired in their interactions with everyday events (Forbus and Gentner, 1986). This experience enabled them to construct a set of schemas to interpret the phenomena of motion (Champagne, Gunstone & Klopfer, 1985, Forbus & Gentner, 1986).

These schemas are perfectly adapted to the tasks of everyday life: riding a bicycle, catching an object, etc. On the other hand, these patterns differ markedly from scientific concepts. In some cases, these patterns may even interfere with learning, especially if the teacher ignores them. In this case, there is a great danger that pupils will distinguish school knowledge, which functions at school (for example, in the laboratory), from everyday knowledge, which enables them to react effectively to everyday events (Legendre, 1994).

A second reason for the difficulty of kinematics is the way it is taught in introductory courses in physics. Indeed, kinematics are often approached using a mathematization to which the pupils are not accustomed (Arons, 1990). For example, a common pedagogical procedure involves bringing pupils, at the beginning of the kinematics study, to the laboratory where they measure different properties of the motion they then carry on graphs. Back in class, they analyze the results obtained and perform calculations using formulas to obtain the values of speed and acceleration. However, it appears that pupils perform these various operations without a real understanding of what they do (Trempe, 1989, De Vecchi, 2006).

Finally, pupils' kinematic difficulties may also come from the way they process information. For example, pupils are inclined to make global judgments of comparison without taking into account the initial or final conditions of the motion studied. (Trowbridge, 1979, Trowbridge & McDermott, 1980, 1981, Feltovich al., 1993, Marshall & Carrejo, 2008). Often, even the concepts of speed and acceleration coincide with each other (Dekkers, 1997). These difficulties may prevent pupils from establishing appropriate links between concepts and, as a result, make it difficult for them to understand these (Stavy & Tirosh, 2000). These concepts may be inadequate and differ from the laws that form the conceptual framework of physics (Ploetzner & Spada, 1998).

To facilitate pupils' understanding, it is preferable that the concepts be presented concretely, in the form of physical models (Marshall & Carrejo, 2008). A physical model describes the simplifications, the links, the constraints and the internal structures of the studied phenomena (Greca & Moreira, 2002, Halloun, 1996). By studying various phenomena grouped in the form of physical models, the pupil comes to develop an internal representation of this situation, consisting of the elements chosen to interpret it and the perceived or imagined relationships between these elements (Acher & al., 2007; Greca & Moreira 2002, Halloun 2004). The result of this modeling of phenomena, in which the pupil identifies the different components of the situation studied as well as their relationships, is systematized in the form of better structured and more adequate cognitive schemas to perform certain scientific functions, for example to explain a more varied range of phenomena (Anderson & Roth, 1989, Halloun, 1996, Marshall & Carrejo, 2008).

To make it easier for the pupil to handle the experimental process required for these modeling activities, it is preferable to introduce the study of phenomena in a qualitative form for several reasons: 1) qualitative reasoning is familiar to pupils because it is used in everyday life (Forbus & Gentner 1986, Legendre 2002); 2) qualitative reasoning allows pupils to better discern the links between concepts because they are not distracted by the need for extensive mathematization (Champagne & al., 1985); 3) qualitative reasoning facilitates the recognition of the limits of the solution found and the constraints of the physical situation (Mualem & Eylon 2007, Goffard 1992).

On the other hand, there are limits to qualitative reasoning: 1) in several situations, it remains indeterminate, since it is not possible to predict the outcome (Crepault, 1989, Parsons, 2001) ; 2) it does not discern the relationships between several variables because it remains limited to the comparison of changes between pairs of variables (Someren & Tabbers, 1998); 3) The units of the variables are not taken into account because these units are determined by the measurement process that refers to the existence of an operational definition of the concept (Arons, 1990, Mäntylä & Koponen, 2007).

On the other hand, quantitative reasoning makes it possible to specify the functional relations that the variables relevant to a phenomenon have between them. In addition, this reasoning makes it possible to consider the interactions between several variables. Finally, the formulation of a rule in the form of an equation makes it possible to explain the properties of a phenomenon in the form of a system of relations of great generality (Mäntilä & Koponen, 2007, Safayeni & al., 2005).

Nevertheless, this type of reasoning is unfamiliar to the pupil so that he may have difficulty connecting various quantities together. Indeed, in order to solve problems requiring quantitative reasoning, pupils often resort to superficial methods of solving the problem of choosing a procedure on the basis of indices provided in the statement (Goffard 1992, Mestre & al., 1993). To overcome these shortcomings, the combination of qualitative and quantitative reasoning in a problem-solving strategy allows pupils to better understand physical concepts and improve their problem-solving skills (Gaigher & al., 2007).

Nevertheless, if this combination seems to improve physics learning, the way how to coordinate them still needs to be determined. To this end, different approaches have been suggested (Parsons, 2001). Among these, two approaches have been used in physics teaching. A first approach is to apply them one after the other. In this approach, qualitative reasoning favors the expression of a small group of plausible hypotheses about the properties of a phenomenon from a set of possible hypotheses (Parsons, 2001). Subsequently, the formulation of these hypotheses in a quantitative form makes it possible to specify among this small group the few hypotheses to be verified (Someren & Tabbers, 1998). The second approach, which integrates qualitative and quantitative reasoning, begins with the qualitative description of the properties of the phenomena and their classification in the form of relationships. The experiments are designed to transform the identified qualities into measurable quantities (allowing, for example, the operational definition of temperature) and qualitative relationships into quantitative laws (Koponen & Mäntylä, 2006). Nevertheless, these two approaches do not take into account alternative conceptions that pupils may have about the phenomenon being studied so that pupils may find it difficult to identify the relevant factors and to express them in a form that facilitates the quantitative formulation by pupils (Ploetzner & Spada, 1998).

To establish links between understanding and reasoning, both qualitative and quantitative, these processes must be mobilized and used in pedagogical contexts that allow exchanges between pupils and favor interaction with phenomena (Trudel, 2005). In this respect, it seems that pupils, in the Someren and Tabbers (1998) study, worked alone. Working in groups, especially when sharing information and exchanging points of view, such as in a small group discussion, allows pupils to access many sources of information and information. to open up to a diversity of points of view, which can favor the formulation of hypotheses (Trudel & Métioui, 2008). When combined with the exploration of phenomena, this approach provides feedback from the results of manipulations that limit the number of assumptions made, which is a prerequisite for the practical verification of these (Gunstone & Mitchell, 1998 Trudel, 2005).

However, it seems that, with regard to the study of phenomena, pupils have little opportunity to propose their own hypotheses in science laboratories (Nonon & Métioui, 2003, Trudel & Métioui, 2008). In addition, a study of the protocols proposed by the laboratory manuals in Quebec shows that pupils are seldom offered the opportunity to engage in an authentic research approach, the steps proposed by these manuals focusing on procedures for data collection and analysis (Métioui & Trudel, 2007). This high degree of structure of the tasks proposed in the laboratory can be explained in different ways: 1) a certain "pragmatic" conception of science leads teachers to prefer laboratories to guide pupils to the correct answer using proven methods and the pupils to be satisfied with having obtained the desired answer (Legendre, 1994, Toplis, 2007); 2) autonomous research would require mastery of several scientific skills, including identification of variables, quantification, coordination of facts and assumptions, etc. (de Jong & van Jooligen, 1998); 3) time and equipment constraints do not permit the repetition and modification of experiments (Toplis, 2007); 4) experience is seen more as a means of testing a hypothesis rather than discovering it (Koponen & Mäntylä, 2006).

To overcome these drawbacks and thus facilitate a more authentic investigation of scientific phenomena, the use of technology would facilitate and increase both the quantity and the quality of the data collected on the phenomena while supporting the pupil in his approach (Jonassen, Strobel & Gottdenker 2005, Hofstein & Lunetta 2004).

Such an approach, called a computer-assisted laboratory, has several advantages: 1) it allows the pupil to focus on the generation of hypotheses and the interpretation of results, two skills that are not well developed in traditional laboratories (Gianono, 2008); 2) it allows the pupil to quickly generate and verify several hypotheses, by facilitating in the latter the strategies of variation of parameters necessary to formulate hypotheses about the properties of phenomena (Riopel, 2005); 3) in physical situations where it is necessary to revisit the results of an experiment to verify its quality or possibly to modify the original hypothesis, computer-assisted experimentation may allow the traditional laboratory's approach to become iterative despite the constraints of the school environment. Indeed, it is often necessary for pupils to look back at the results of an experiment to study the causes of the gap between their ideas and the results obtained, thus promoting conceptual change in science (Trudel, 2005).

In light of the above, a learning approach aimed at facilitating the transition from qualitative reasoning to the discovery of quantitative laws should include provisions to promote the expression and comparison of pupils' ideas with each other (eg small groups) and provide pupils with the opportunity to quickly and easily test their ideas using experiments supported by data collection and analysis software (Riopel, 2005, Trudel, Parent & Métioui, 1989). The iterative nature of this approach, which mobilizes both qualitative and quantitative reasoning, should enable pupils to gradually build a scientific model of observed phenomena (Acher & al., 2007, Schwarz & White, 2007).

Our research objective is therefore to develop a learning approach to facilitate the induction of quantitative rules on motion through the prior use by pupils of qualitative reasoning in a discussion among pupils about the kinematic phenomena studied in the framework of a computer-assisted experimentation.

Design of The Teaching-Learning Sequence

In order to study the transition (or coordination) between qualitative and quantitative reasoning, we need to design a learning process that can produce the desired changes (Siegler, 2006). To this end, we have designed a scenario of the activities as described in the previous section. This scenario specifies the different pathways that pupils can take to develop a better understanding by taking into account the particular difficulties they may encounter in their learning. This scenario includes the goals of the activities, the structure of the content of the field studied, the pathways followed by the pupils to reach their goals, taking into account the misconceptions they harbor and the activities offered to the pupils. The purpose of the activities is to help pupils develop a better understanding of kinematic concepts and problem-solving skills through an approach combining qualitative and quantitative reasoning about the properties of motion phenomena. The suggested approach aims to help pupils modify their schemas in stages so that they move progressively closer to kinematic concepts.

To represent the kinematic phenomena, we organized them into physical models. In kinematics, there are three models (Halloun, 2004): the constant speed motion in a straight line, the uniformly accelerated motion and the mixed motion that combines the first two. These models assisted us in designing specific activities to help pupils understand the different aspects of the motion. To facilitate the modeling of kinematic phenomena by pupils, we must determine the different ways pupils understand motion and consequently the different routes they can take in their learning.

To this end, we have designed networks of understanding the concepts of kinematics. These networks of understanding consist of two types of information: 1) the main concepts of kinematics, such as speed or acceleration, and their interrelationships; 2) indications of pupils' misunderstanding of these concepts (Klir, 2001, Trudel, Parent & Métioui, 2009). Once the conceptual structure of the domain and the misunderstandings identified, we organized learning activities to support the different routes that pupils can take by developing a better understanding of the properties of the motion (Méheut & Psillos, 2004).

With regard to modeling of kinematic phenomena, we have designed activities to meet the characteristics of the different models previously described: uniform rectilinear motion, uniformly accelerated motion, and mixed motion. To allow pupils to work in small groups (about four pupils), we have designed an activity guide to guide the pupil's approach. The guide contains cases to study different aspects of motion grouped in the three kinematic models described above. Each case includes activities (questions, graphs to complete, etc.) that guide the process of modeling pupils. The modeling process is structured according to a POE task (Prediction> Observation> Explanation) (Gunstone & Mitchell, 1998).

Each POE task runs as follows. A physical situation, represented in concrete form by a physical set-up, is explained to the pupils in the guide. Questions associated with this case ask the pupil to predict what will happen if the experiment is done. They then write down their predictions in their notebook. Pupils in groups of four then assembled the set-up associated with this case according to the guide's instructions. They observe the properties of the targeted motion and write their observations in their notebook. They then try to explain the gap, if any, between their predictions and their observations. In doing so, they can modify the set-up to study other aspects of the motion or to check alternative hypotheses emitted during their exchanges.

The verification of pupils' hypotheses is done in small groups at the computer-assisted laboratory. First, the videos of the balls rolling on rails at different inclinations are captured with a digital camera in the video recording position. The contents of the sequences filmed by the camera are transferred to the computer and transformed into a video file by the Quick Time software. Once in this form, the image sequences can be viewed as in a movie. Having inserted these sequences of images in the REGAVI software, the pupil can use the mouse with a cursor to take measurements of the successive positions of the ball as a function of time. These measurements are immediately tabulated by the REGAVI software. In addition, this software contains features for choosing reference axes, tracking the motion of multiple objects at a time, and matching the position and time intervals in the video with the positions and times measured at the experiment itself. Subsequently, the data tables provided by the REGAVI software can be transferred to the REGRESSI analysis software for analysis. The latter software has features that allow the user to make different graphs of position, speed and acceleration as a function of time. In addition, the REGRESSI software facilitates the discovery of relationships between variables by providing means for comparing the fit of different curves (linear, quadratic, exponential, etc.) to the data obtained.

Unfolding of the activities

We have implemented various aspects of the approach described in the previous section in several classes of high school pupils and the training of future science teachers (Trudel, 2005, Trudel and Métioui, 2010). We were inspired by the logbook information from this research and the results of the analysis of pupil responses in the pupil handbook to specify, based on the characteristics of the samples, the progress of the proposed approach in the classroom (Altrichter & Hollly, 2005). For the sake of clarity, we have chosen the three most significant cases in our case among those constituting the proposed approach (Trudel, 2005).

First case
The first case submitted to pupils consists of a POE task (see Figure 1) shows an excerpt from the description of this case in the pupil's guide (Trudel, 2005):
"A ball is thrown on a horizontal rail. The gray circle indicates its initial position at launch. The circle with the symbol 1 inside indicates the position of the ball after 1 second.”

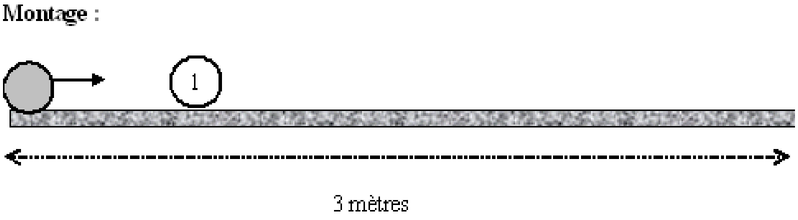

Figure 1 Motion of ball rolling on an horizontal track.

The POE task then consists in predicting what will be the successive positions of the ball every second, knowing the distance traveled in the first second. From these predictions, the teacher asks his pupils to draw a graph of what the position of the ball would be as a function of time. Indeed, it is important to encourage pupils to specify their prediction in a concrete way in order to compare it more easily to experimental results (White and Gunstone, 1992).

The teacher then proceeds to carry out the experiment. Then he asks them to explain any discrepancies, if any, between their predictions and their observations of the motion of the ball. It should be noted that the conceptions of pupils appeared similar from one group to another, and from one level of teaching to another (Trowbridge and McDermott, 1980, 1981):

1) The speed of the ball increases in the first part of the path, remains constant in the middle part, then slows down thereafter. It should be noted here that among the pupils who attribute an acceleration to the ball initially, some tend to confuse the initial time with that when the ball is set in motion by the experimenter.
2) The speed of the ball remains constant until the end, without noticeable slowdown. Some explain that the length of the rail is too short or that the slowdown is too slow to be detected.
3) The speed of the ball decreases gradually until it stops. Pupils who maintain this conception invoke friction as the cause of slowing down.

During classroom discussions, some pupils justified their choice of a conception based on visual evidences such as the ball appears or does not seem to slow down. At this stage, the pupils themselves propose to measure the velocities over intervals of time and distance chosen using stopwatch and meter. It is then possible to turn the discussion into experimentation in small groups. During the experiment, the sequences of the motion of the ball are collected using a digital camera and subsequently transferred to the REGAVI software and then to the REGRESSI software for measurement and analysis of the position and speed of the ball according to time.

The positions and times obtained are then tabulated and then plotted on position-time and speed-time graphs. In general, the computer system allows the pupil to measure the motions of the ball in the different successive time intervals and thus establish the constancy or not of the speed. In addition, the study of the shape of the curve of the position as a function of time makes it possible to compare it to the expectations of the pupils as to the form of this motion established in the prediction part of the POE task.

By providing various feedbacks, whether in pupils' exchanges or comparison of expectations with the results of experiments, such an approach is likely to facilitate a better understanding of kinematic concepts. Indeed, by comparing the shape of the two curves, pupils realize that, contrary to their expectations, the motion between successive time intervals is identical and that friction plays a negligible role. For pupils at higher levels, whose mathematics training is more advanced, it is possible with the REGRESSI software to compare the fit of the curve to different functions, whether they are linear, quadratic or other. So in this case, the curve obtained by the REGRESSI software is as follows:

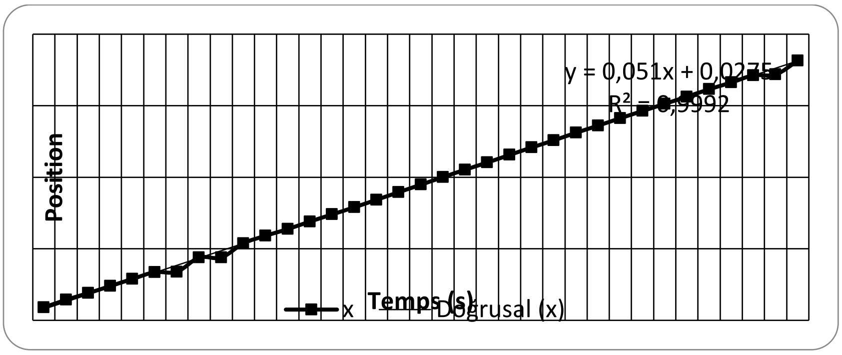

Figure 2 Position-time graph in case of uniform rectilinear motion

Second case

In addition, it is possible to consider complex physical situations (see Figure 3).

Montage : Deux billes A et B sont relâchées en même temps du haut du premier rail incliné. Elles sont séparées initialement par une distance d'environ 5 cm.

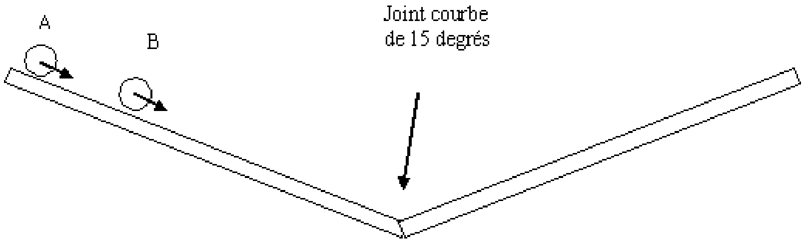

Figure 3 Motion of two balls separated by an initial distance down a system of two tracks making an angle

The teacher then asks the pupils if Ball A will eventually catch Ball B. In the Prediction section, he asks pupils to predict the respective positions of Balls A and B over time. In addition, he asks them from their predictions to plot the position-time and speed-time graphs of the two balls. In general, if the pupils have understood the previous cases concerning the acceleration of balls going down or down an inclined rail, they can study this situation and contribute to classroom exchanges. The debates that result from this scenario can be lively because it is a complex situation that includes an interesting issue, the prediction of the properties of a motion familiar to pupils.

In particular, the prediction of the position-time graph presents a particular difficulty because it consists of an upward parabola (acceleration) followed by a downward parabola (deceleration) (see Fig. 4). In this respect, the continuity of the speed, represented by the tangent to the position-time curve, allows that there is a point of inflexion between the two trajectory segments. As a result, this is a challenging situation for pupils of all levels. Nevertheless, the familiar nature of this motion situation makes it possible for everyone to participate in the discussion by making assumptions. In particular, some pupils may argue that the distance between the balls will not vary in the first segment, as the acceleration along the inclined plane is the same as well as their initial velocity (which is zero). Only when they go back does the motion become asymmetrical. Indeed, the ball A having descended the first part over a greater distance will start the second part with an initial speed greater than the ball B. In certain conditions which depend mainly on the initial distance between the two balls, the ball A will be able to catch ball B before it has reached the top of its trajectory.

This situation involves many concepts and we lack space to describe the different strategies adopted by the pupils. Even if it is possible by reasoning to provide convincing arguments in support of any of the ideas expressed by the pupils, the possibility of quickly taking data from the positions of the two marbles as well as amkinf readily position-time and speed-time graphs allow pupils to sort out various opinions and move toward a deeper understanding of the concepts involved.

Figure 4 shows that the position as a function of time corresponds to the juxtaposition of two parabolas, one upwardly downward and the other downward upward. As expected, the point of inflexion between the two parables is halfway.

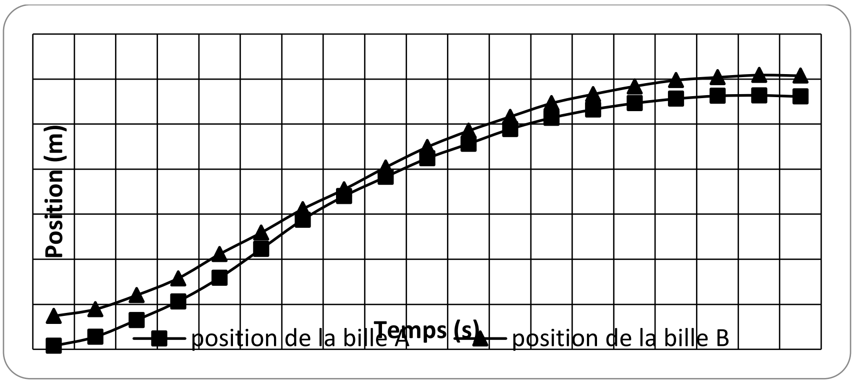

Figure 4 Position-time graph of the two balls in pursuit

Figure 5 below shows the speeds as a function of time of the balls A and B of this case of pursuit. It is noted in the first part of the path that the speeds of the two balls increase regularly with the same acceleration (the slopes of the lines are substantially the same). The two balls reach their maximum speed then decrease to zero. It is interesting to note that the final speed of the ball A is greater than the speed of the ball B (which could be predicted taking into account that the ball A is accelerated over a greater distance than the ball B). On the other hand, it is also curious to note that, in the second part of its trajectory, the speed of the ball A is lower than that of the ball B. This inversion takes place after the speeds of the balls A and B have become equal, at a time of about 7 seconds. A plausible explanation would be that the balls A and B then collided and some of the impact contributed to the decrease in the speed of the ball A.

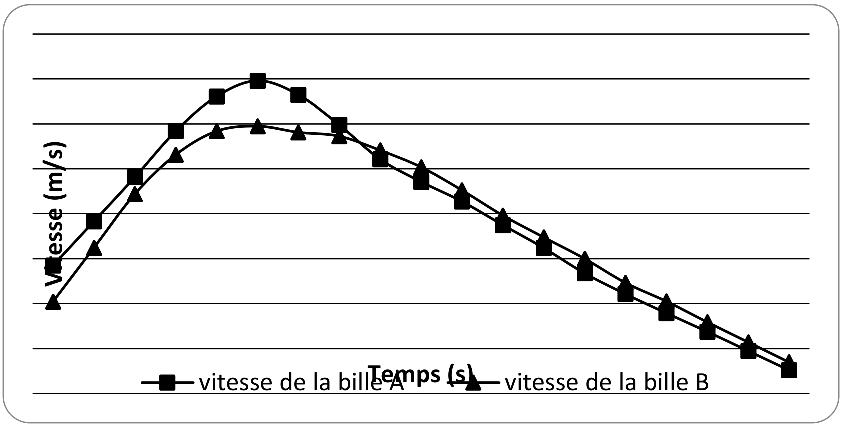

Figure 5 Speed-time graph of the two balls in pursuit

Third case

The third case is an example of a single ball whose segments of the trajectory have different motions (see Fig. 6):

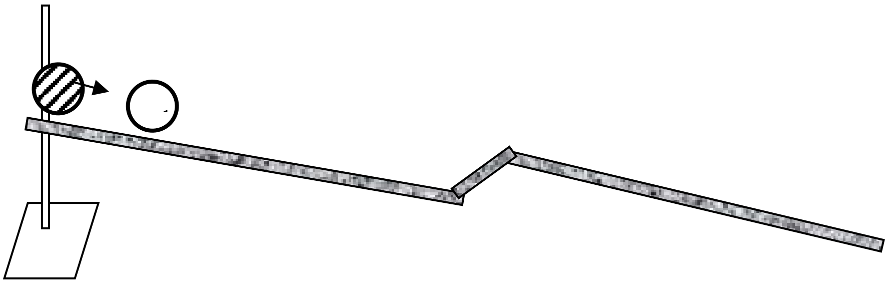

Figure 6 Ball rolling down an inclined track with a bump

In this case, the teacher asks the pupil to predict the different positions of the ball as a function of time. This case is an application of the concept of instantaneous speed and should be presented to pupils after they have studied the characteristics of accelerated motion and those of decelerated motion. To solve this problem, the pupil must juxtapose several parabolic motions in order to respect the continuity of the speed at the junction points. In Some pupils went so far as to invoke considerations of energy conservation. So, depending on where the ball is dropped, she might or might not have the energy to overcome the "bump".

The following graph shows the position of the ball as a function of time (see Fig. 7). We note that the first part of the motion is represented by a parabola directed upward (downhill) followed by a parabola section pointing downwards (raising of the hump) and finally again with a parabola facing upwards (descent again). It should be noted that the "mechanical" use of the regression could give us a line as a best curve, whereas by the discussion, most pupils can easily juxtapose the curves corresponding to each segment of the trajectory.

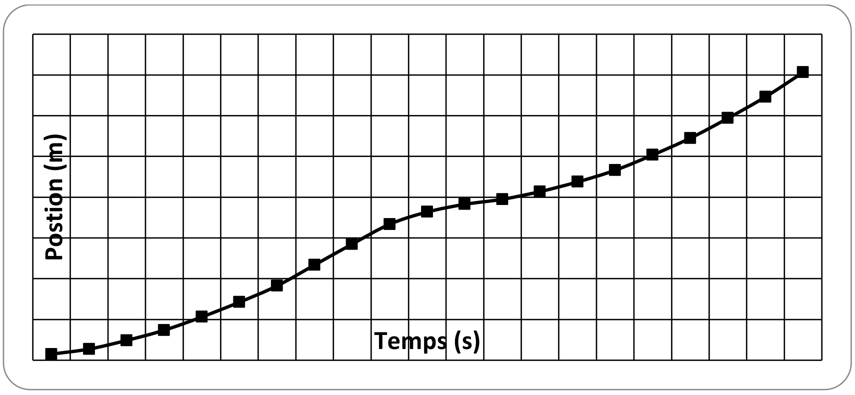

Figure 7 Position-time graph of the ball undergoing successive accelerated and decelerated motions

Discussion and Conclusion

The use of computers in the physics laboratory is revolutionizing the teaching of this discipline. Nevertheless, computer-assisted experimentation is too often devoted to the technical side of automated data acquisition and its organization in the form of tables and graphs. This emphasis on the technical accuracy of the measures, despite its rigor, may obscure the need for judgment.

It is one of the essential characteristics of common sense to be able to understand the physical phenomena that surround us without having to go through advanced mathematization, which is not very effective in solving everyday problems. Nevertheless, it is not a question of abandoning the mathematization of the properties of the phenomena but of approaching it when the essential elements of the problem have been understood by the pupils.

The approach presented here proposes to use the capacities of the computer so that the pupil can, from a representation of common sense, of qualitative nature, of the properties of the phenomena, to pass to a mathematical representation in the form of position-time and speed-time graphs. Our semi-quantitative approach allows, through reasoning, pupil-to-pupil exchanges and the use of various modes of representation, for high school pupils to study kinematic phenomena of a complex nature, previously reserved for postgraduate education, college and university in particular. These still embryonic results seem promising.

In particular, studies involving groups of pupils under controlled conditions, difficult to reproduce in the heat of the teacher's daily action, would make it possible to follow the progress of pupils when they make the transition between their common sense representations and scientific representations. To date, research in science didactics has studied pupils 'understanding of simple phenomena in which pupils' conceptions have mostly been acquired through the observation of everyday phenomena. However, studying pupils' alternative conceptions when they are experimenting with the properties of complex motion phenomena would allow us to better understand how these pupils relate the various kinematics concepts needed to solve them.

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