MODELING WITH STAGECAST CREATOR^{TM}: A VIDEO-CASE STUDY DESCRIBING THE PROCESS OF DEVELOPING, EVALUATING AND REFINING MODELS OF ACCELERATED MOTION IN ELEMENTARY SCHOOL[1]

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ABSTRACT
This paper describes a video case study from an elementary science/computer after-school club during which eleven sixth graders used Stagecast Creator™ to develop computer-based models of accelerated motion. Research in model-based learning in science has highlighted the usefulness and importance of scientific modeling for learning and teaching in science. However, it has thus far failed to provide details about the student discourse that teachers need to encourage during scientific modeling, as well as descriptions of how modeling really looks in the science classroom. Through the investigation of authentic classroom-based discourse and student-constructed models, our purpose in this paper was to describe in detail the process of developing, evaluating and refining models of accelerated motion, seeking to refine our understanding about learning in science through the construction of models as representations of physical phenomena and inform teachers about how productive modeling discourse may look. Using discourse-based conversational analysis, we analyzed a series of whole-class student conversations that happened over the course of three 90-minute meetings, seeking to describe the context and the content of the conversation, and to describe in as much detail as possible instances of productive collaborative scientific modeling. We also analyzed 15 student-constructed models using a modified version of artifact analysis, seeking to identify features that previous research has highlighted to be important parts of scientific models. The findings of the study present a detailed sequential description of the modeling discourse, computer work and student-constructed models, following student work in as much detail as possible up until the development of what students thought satisfactory models of the accelerated motion. Implications about the role of Stagecast Creator as a computer-based tool for scientific modeling in early science education are also discussed.

KEYWORDS
Modeling-based learning, Stagecast Creator

INTRODUCTION

Modeling, that is the process of constructing models as representations of physical phenomena, is an essential part of science. Science proceeds through the construction and refinement of models. In this sense, a physical system may be represented through a model by identifying the physical objects involved, their behaviors and their characteristics and the interactions among these objects, their behaviors and their characteristics (Constantinou, 1996).

The process of constructing models can be also viewed as an approach for learning in science, which entails learning for and about models; that is, learning both the models of the physical phenomena that scientists have developed (Constantinou, 1996; Golin, 1997), as well as the process of developing and refining them (National Research Council, 1990; White & Frederiksen, 1998). Models and the process

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of scientific modeling have been highlighted as core components of science education (diSessa, Abelson, & Ploger, 1991; Justi & Gilbert, 2002; Redish & Wilson, 1993; Sherin, 1996; Sherin, diSessa, & Hammer, 1993; White & Frederiksen, 1998; Wilensky & Resnick, 1999).

Our purpose in this paper is to describe a detailed video-case study that includes the process of elementary students' developing, evaluating and refining models of accelerated motion. In this effort we seek to refine our understanding about learning in science through the construction of models as representations of physical phenomena and inform teachers about how productive modeling may look.

THEORETICAL FRAMEWORK

Modeling-based learning in science

Modeling-based learning can provide the context in which the development and refinement of models can achieve better quality outcomes in terms of fundamental understanding of concepts, operational understanding of the nature of science and the ability to employ procedural and reasoning skills, than what is currently possible through other learning environment/tool (Harrison & Treagust, 1998; Bell, 1995; Grosslight et al, 1991). Learning approaches that are grounded upon the premises of modeling-based learning offer students opportunities to think and talk scientifically about natural phenomena (Penner, 2001), to share, discuss and criticize their ideas (Devi et al, 1996) and to reflect upon their own understanding (Gilbert et al, 1998).

The modeling-based learning Cycle

Research in science education has highlighted a number of modeling-based learning approaches in science (see Justi & Gilbert, 2002, for a review; also see Constantinou, 1996; Penner, 2001; Penner, Lehrer, & Schauble, 1998; Schecker, 1993; Gobert & Buckley, 2000; Glynn et al, 1994; Treagust et al, 1996; Gilbert, 2004). Nevertheless, all researchers agree that the modeling-based learning approach involves two basic stages: the model formulation stage and the model deployment and evaluation stage.

During the model formulation stage students develop a working conceptual model about a physical situation. After they identify the need to describe, predict and/or explain a physical phenomenon, the learners need to investigate the phenomenon in order to develop a model to represent it. They can use empirical observations or their everyday experiences to simplify the physical world into objects and their interactions to be represented in their models. To do that, students also need to identify the usefulness of establishing new concepts (representing physical entities), which are usually used in the constructed model as aspects of the physical system, or as descriptors of the processes or interactions among the various entities comprising the system (Constantinou, 1999; Hestenes, 1992; Schecker, 1993). The interpretation of collected data and prior experiences can lead to the development of a network between several fundamental concepts. At this point, a first model of the scientific situation has been developed (Constantinou, 1999).

After a model is constructed, students are ready to go through the second stage of the modeling-based learning approach, which includes the deployment of the model in a new situation. They need to evaluate their model through a comparison with the real-life phenomenon (Bell, 1995; Papaevripidou, Constantinou and Zacharia, in press; Penner, 2001; Penner, Lehrer & Schauble; 1998; Schecker, 1993; Gobert & Buckley, 2000). To do this, it is important to decontextualize the model and its invented concepts and essentially reformulate it in a new context in a way that enables them to make testable predictions. This is useful because it provides feedback information for further model improvement but also because it illustrates the practical significance of model formulation.

The deployment process also requires that students use the model not only in interpreting phenomena, but also in making predictions about other ones. The modeling process does not end here. So far, students have been developing simple models – interpreting parts of the physical phenomenon. This implies a step-by-step development of the model from a simpler stage to a more advanced level (Golin, 1997). "…complex theories in science are developed through a process of successive elaboration and refinement in which scientific models are created and modified to account for new phenomena that are uncovered in exploring a domain" (White and Frederiksen, 1998, p.7). The idea is to keep the model-based learning cycle going with testing, revising and re-evaluating the constructed models (Bell, 1995).

Computer-based programming as modeling tools

Modeling-based learning is, of course, related to the modeling tools used (drawings, mathematical equations, graphs, concept maps, three-dimensional structures, computer-based programming media and computer-based modeling environments). One promising modeling tool that appears in the literature is the computer-based modeling environments (diSessa, Abelson, Ploger, 1991; Redish & Wilson, 1993; Sherin, 1996; Sherin, diSessa, & Hammer, 1993; White & Fredriksen, 1998; Wilensky & Resnick, 1999: Louca, 2004).

A computer-based modeling environment consists of an open-ended, dynamic and exploratory learning environment which supports the construction of representation of complex phenomena or natural systems through the simultaneous execution of multiple processes that go beyond static, to dynamic representations of cause/effect relationships (Sins, Savelsbergh & van Joolingen, 2005).

Currently, a large number of computer-based modeling environments are available and suitable for educational purposes. In this study we have used a software title from a particular family of computer-based modeling tools, namely, computer-based programming environments (CPEs) that research has confirmed their importance of being used as tools for teaching practices of modeling and science. Additionally, the process of scientific modeling can be compared to the process of computer programming, and modeling can be carried out through developing a computer program, when the program itself becomes the scientific model (Louca, 2004; Louca & Zacharia, in press).

CPEs provide a microworld environment that has no rules and follows no physical laws, and provide a program language as the modeling tool for developing representations of natural phenomena (Pea, 1984). In contrast to other computer-based modeling tools that can be used only for the construction of symbolic simulations (models), CPEs enable users to develop "concrete" simulations of physical phenomena that can include animation-like representations of those phenomena that are result of the program code. To represent natural phenomena through computer microworlds, students have to deconstruct their understanding into small programmable pieces of knowledge, in order to transform an idea in science into specific, technically precise program code. The activity of programming may also bring the constraint of formal precision. Students learning science often struggle with terms such as "force" or "acceleration" that have everyday, context-dependent meanings. Science students need to learn new, more refined meanings of these terms, but, as importantly (and as difficult to accomplish), they need to learn the practice of quantitative precision: For an idea to be useful in science, it should be made sufficiently precise in order to maintain consistent meaning across different contexts (Hammer & Elby, 2003). Like mathematics, programming can be a language for using in developing understanding in science (Sherin, 1996), which can also help students to develop new, refined meanings of terms (Hammer & Elby, 2003).

Stagecast Creator

Stagecast Creator is the CPE that we used in this study. It is entirely based on a graphically represented program language. Programming in Stagecast is done by demonstration, using "click-and-drag" techniques (Smith and Cypher, 1999). During programming, the software records the user's actions storing them in a script consisting of visual "if-then rules" rules: for a given situation, an action is determined (Smith & Cypher, 1999). Rules are executed sequentially based on whether each rule's condition is met. Every machine cycle, Stagecast runs a rule for each object from its rule list.

Programming in Stagecast Creator is also object oriented: the user has to assign each character with its own rules that define its behaviors and its characteristics. Variables are clearly differentiated from the rest of the code, represented with boxes named after the variables and located below the list of rules of each object. They can be easily incorporated in the program by simply dragging them into a rule. Rules and variables are stored "behind" each object, where they can be reviewed any time, even during running a program: by double-clicking on an object, one can review its rules and variables. Lastly, Stagecast Creator uses analogical representation: an object is represented in the same way in all different levels of the software (the program level, the outcome/simulation level etc). This way, the graphical environment used allows direct manipulation of the represented objects and easy assignment as well as direct review of the rules to each object (Smith & Cypher, 1999).

METHODOLOGY

We carried out this study in Cyprus, as part of a larger study aimed to develop video case studies for student modeling through different CPEs. It involved a single group of eleven sixth grade students at a metropolitan elementary school, where we set up an afternoon computer/science club. All students volunteered to participate in the study. Students met with a teacher and the first author once a week for 90 minutes for a total of 7 months during the school year of 2005-2006.

The data reported in this study originate from three 90-minute meetings during which students studied and developed models of accelerated motion. Student work involved working in small groups with the CPE or having whole class conversations about the phenomenon or the models they developed. For the purposes of this paper, we focus on the conversations they had in the whole class settings talking about the phenomenon or evaluating each other's models, and on the models students developed as a result of those discussions, seeking to provide a detailed description of how learning in science through modeling looks in the authentic learning environment of the science classroom we studied.

We used two sources of data as the primary data sources. First, video data from whole class conversations along with the verbal protocol from the transcripts served as the first primary source of data. We analyzed them interpretively (see Analysis I) with a focus on the micro-context of the conversation in terms of scientific modeling. Second, student's models were also collected and analyzed (see Analysis II) to support claims from the first analysis.

Data Analysis I: Narrative analysis of student discourse

Our first analysis follows approaches for analyzing student conversation in science and mathematics (e.g., Ball, 1993; Gallas, 1995) and shares the interest of the science education community in classroom discourse (e.g. Kurth et al., 2002; van Zee et al., 2001; Hogan, Natasi and Pressley, 2000; Roschelle, 1992). This analysis uses transcribed student conversations as a gateway to student thinking and experience, drawing on methodologies that have been used in linguistics, educational psychology research and educational research (Edwards & Mercer, 1995).

Table 1. Codes used for the artifact analysis, adopted from Michael, Louca & Constantinou, 2006

Category	Codes
1. Representation of physical objects	1.1. Physical objects internal to the physical system
	1.2. Physical objects external to the physical system
2. Representation of object behavior (interactions among physical entities)	2.1. Non-causal
	2.2. Semi-causal
	2.3. Causal
	2.4. Scientifically correct
3. Representation of object characteristics (physical entities)	3.1. No representation of physical entities
	3.2. Represented with a numerical value
	3.3. Represented with a variable a numerical value
	3.4. Represented with both a variable and a numerical value
4. Representation of interactions between:	4.1. Objects
	4.2. Variables
	4.3. Procedures

We used discourse to develop detailed accounts of the context and the content of the conversation and possible relations between them. Although our approach uses the same data source with discourse analysis (Sinclair & Coulthard, 1975), it does not seek to reveal the structure of the conversation (Edwards & Mercer, 1995), but rather the content of what is said. For this reason, we have developed detailed descriptions of the conversation, as well as possible interpretations of student thinking in terms of scientific modeling. Our presentation of findings below involves a number of small conversational excerpts that we selected to support our claims.

Data Analysis II – Artifact Analysis

To support findings from the narrative analysis, we also analyzed student-generated models. At the end of each meeting we collected all the models that each group of students constructed. A total of 15 models were collected and analyzed (5 groups of students x 3 models each). We analyzed models using artifact analysis adopted from a different study (Michael, Louca & Constantinou, 2006) that was part of the same larger research project. Codes from this analysis included the ways that students represented different elements in their models: physical objects (characters), object characteristics and object states (variables), object behaviors (procedures), and interactions among objects and their characteristics. Table 1 presents the different codes used during the artifact analysis.

FINDINGS AND DISCUSSION

The presentation of findings below follows the temporal sequence of how the discourse evolved over the three 90-minute meetings studied. The teacher started the conversation by stating the question: “A boy is standing at the edge of a cliff and he is about to let a ball fall. What would happen to the ball?” After making sure that students understood the situation, he explained that their job was to develop a simulation with Stagecast that would show what would happen to the ball. The teacher also emphasized that student models should be as close as possible to the reality and he then let students start working on their first models in small groups. It should be noted that all students had already some experience of using Stagecast Creator to develop models.

I. Presentation of students’ first models

After allowing some time for working on their first models, the teacher asked students to present their models. The first to present were Georgia and Erini (group 1), who developed a Stagecast Creator rule that had the falling ball moving one square down per machine cycle (Figure 2a). Nasia and Myrianni (group 2) developed a rule that moved the ball from the top of the cliff to its very bottom in a single step (Figure 2b): that is in one machine cycle, the ball is moved from the top to the bottom of the cliff. Constantinos and Loucas’ (group 3) model was the same as group’s 2. Paris and Panayiotis’ group (group 4) developed a model in which the ball moved first horizontally (“on the air”) and then downwards, in an effort, as they suggested, to make it move diagonally assuming that the boy did not just let the ball, but kicked it first. Dioni’s model was similar to Georgia and Erini’s, having the ball move the same number of squares per machine cycle, although she thought that the traveling distance per machine cycle should had been larger (4 squares per machine cycle) (Figure 2d).

The artifact analysis showed that students’ first models had a representation of the object’s behavior in a non-causal manner: there was no representation of what was causing the ball to move to the ground. They also had no formal representation of physical entities such as velocity and acceleration, and no representation of interactions among objects, variables and object behavior.

II. Discussion of similarities and differences among their first models

With the exception of Paris and Panayiotis’ model, the rest of the models students constructed had a common characteristic: they included rules that created a model of motion with constant velocity, whereas the phenomenon under study required a model of accelerated motion. The teacher decided to focus the discussion on this issue. He started by asking students to talk about the differences among their models. Students easily identified that their models had different numbers of squares that the ball moved in every machine cycle, implying that the speed of the falling ball differ across different models.

After agreeing on this, the teacher directed the discussion on the similarity that all these models shared. The following short excerpt is taken from that discussion.

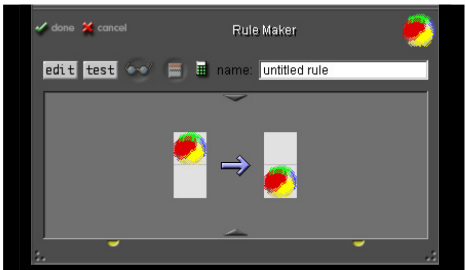


Figure 2a. Georgia & Erini's first model

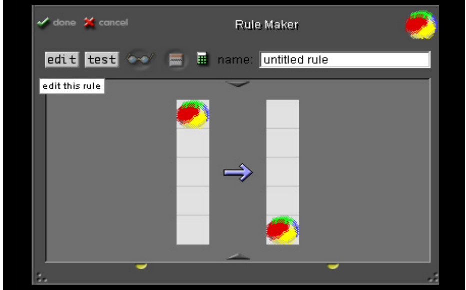


Figure 2d. Dioni's first model

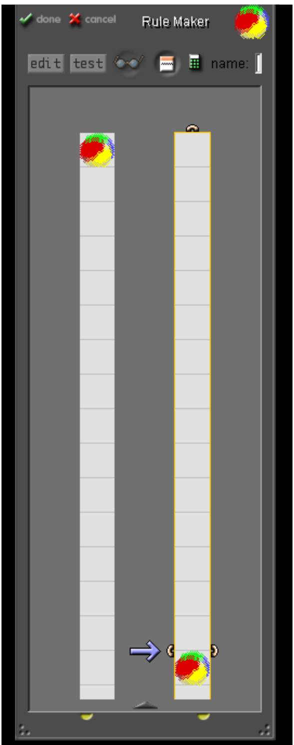


Figure 2b. Nasia & Myrrianni's first model

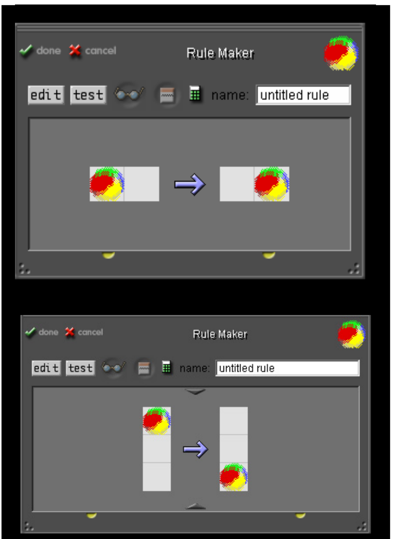


Figure 2c. Paris & Panayiotis first model

Figure 2. Students' first models

Teacher: Ok. So let me just say again that we need to show how the ball would fall if the boy let it fall without any push or kick. Ok? Now, about the way all of your models show the ball falling. Are there any similarities?
Panayiotis: No, in all of them [models] the ball moves the same.
Teacher: What do you mean?
Panayiotis: It moves 3 squares every time.
Teacher: Yea, but Dioni had her's going four [squares each time] and the girls [Georgia and Erini] has their's one [square each time]. What is the similarity among all these models?
Georgia: The ball moves always the same [number of squares]
Paris: [the ball moves] With the same force!
Teacher: The ball goes with the same force, Paris says… Anyone else?
Georgia: With the same rhythm.
Teacher: With the same rhythm… Do you know any other word that can describe that rhythm and that force when a ball moves?
Georgia: With the same velocity!
Teacher: And how do we call the velocity that keeps always the same?
Constantinos: Constant!
Teacher: Constant.
Panayiotis: Oh, yea, you're right…
Teacher: What does constant [velocity] means?
Paris: It means that the ball will move always the same.

During this discussion, students came to realize that despite the differences, their constructed models shared one common characteristic: they were all models of motion of constant velocity. Coming to realize that was not an easy endeavor, not because students had what research in science education has called “misconceptions” about the phenomenon under study (because there is clear evidence of the contrary), but because, as research has highlighted elsewhere (Louca & Zacharias, in press; Loucas, 2004), during the initial stages of their work with computer media as modeling tools students are often mostly interested in how their simulation looks and not in the science represented in their models.

However, coming to realize that their models represented constant motion had an educational advantage. In the discussion above, students tried to identify a similarity in all their models. To do that, they had to compare and contrast their models in order to reach a consensus about that similarity. That consensus (the representation of constant velocity in their models) was based on a concrete representation of a concept (velocity) in science. After finding that similarity, the teacher asked students to name it, and students were quick to propose the concept of constant velocity. At that point, referring to constant velocity as the similarity in their programs, they had operationally defined the concept of constant velocity as the constant change in the ball’s position.

Now that students had realized that their models represented constant motion, they could proceed to evaluate whether their models represented in an accurate manner the phenomenon under study. The teacher asked them whether they still thought that their models were good representations of the phenomenon under study. The following excerpt is taken from that discussion.

> Teacher: Now that we’ve seen all of the models, let’s remember what your purpose in making these models was. Your purpose was to develop representations of the phenomenon as close as possible to reality. Are you still sure that your models are accurate representations of this phenomenon? Does a falling ball look like this?
> Panayiotis: No!
> Teacher: What do you mean?
> Constantinos: While falling, it [the ball] picks up speed.
> Teacher: What do you mean “it picks up speed?”
> Constantinos: It goes faster. At the beginning it moves slowly, then faster, then even more faster until it reaches the ground.
> Paris: It accelerates!
> Teacher: The ball accelerates! What does it means?
> Paris: The speed is being multiplied…
> Teacher: I see. Any other ideas about what accelerates means?
> Panayiotis: It [the ball] gets faster.
> Teacher: Ok. The ball goes faster. What happens to its speed?
> Constantinos: It keeps changing.
> Nasia: Increases.
> Teacher: It does not simply changes. It increases over time. Do you remember how we called the velocity that stays the same in your first models?
> Myrianni: Yea, constant.
> Teacher: That’s right. Constant. What should we name the velocity that increases over time?
> Paris: Increasing [velocity].
> Teacher: Increasing velocity! Very good! So, now you can go back to your computers and make changes to your models!

Students suggested that their programs needed to be revised to include rules that would create a simulation in which the ball’s velocity would increase. Those models, they suggested, would be models of accelerated (not constant) motion, linking known terms (accelerated motion) with the appropriate concept in an operationally defined manner (the speed of the ball increases every machine cycle). In accelerated motion, they suggested, the velocity increases, meaning that the object would go faster (every machine cycle) and that the velocity (which would be a number or a variable in their models) would increase over time. That increase, Paris suggested, could be represented by multiplying the velocity [with a constant number] in every machine cycle. At this point the teacher felt that he could let students work on revising their models to represent accelerated motion.

III. Presentation of students' revised models

Students spent the next 30 minutes making revisions to their models. Those revisions required some thinking and negotiation in their small groups, as the teacher did not provided students with the time to talk about how they could implement their new ideas about accelerated motion in Stagecast. After all students thought that their new models reached a satisfactory level, the teacher asked them to present their models to the rest of the class. Below we present a short excerpt from the presentation of Constantinos' revised model of accelerated motion, followed by a discussion the deal with the evaluation of their revised models. Constantinos' model is represented in Figure 3 and it is representative of the rest of the revised models.

> Constantinos: I created several rules, each one has the ball move an additional square. And I put them into the "do in turn" [folder] so that the software would run each rule once and then moves to the following [rule] …
>
> Teacher: Can you show us the first rule?
>
> Constantinos: Here it is. It will move the ball one square down.
>
> Teacher: Ok. What about the second rule?
>
> Constantinos: It [the ball] will move two squares [down].
>
> Teacher: Ok. And how many rule do you have?
>
> Constantinos: Seven.
>
> Teacher: And what happens to the velocity in your program?
>
> Constantinos: It increases.

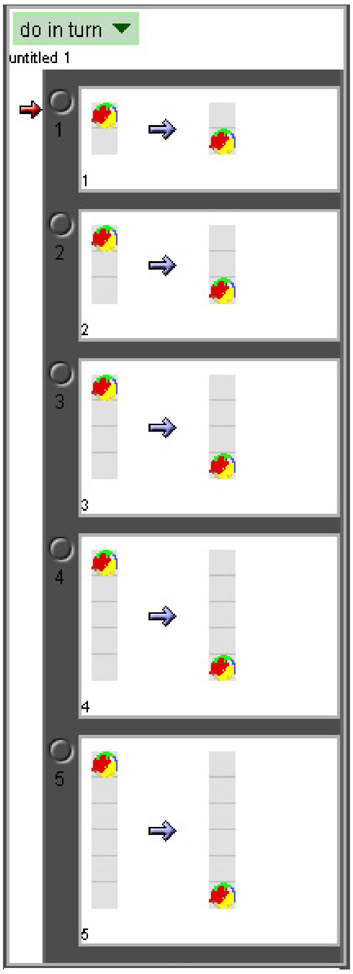


Figure 3. Constantinos' revised model

Constantinos developed a program which had 7 rules that were to be executed sequentially. In each subsequent rule, the ball moved one additional square compared to the previous rule, thus making Constantinos' model a representation of accelerated motion. To make this happen, Constantinos used Stagecast Creator's trick of creating a number of independent rules and putting them in a "do-in-turn" folder, indicating to the system that they needed to be executed sequentially.

Artifact analysis suggests that Constantinos' model did not include representation of physical entities (in any form). For instance, it had no representation of the ball's velocity or acceleration. Similarly, the representation of object behavior (interactions between object and variables) was non-causal, simply describing the behavior of the ball over time in a temporal sequence of events. This makes Constantinos' model simply descriptive and not causal, simply providing scenes from the phenomenon without any representation of what was actually causing the ball to accelerate and the velocity to increase over time.

Constantinos' model had an additional major disadvantage. Because it was descriptive (and non causal) it only worked in this particular situation, and could not be used in different situations where, for instance the ball would have to move a larger distance falling: the ball would move only the distance specified in the rules and to correct that, changes in the code would be necessary. Because of that, as our artifact analysis suggested, this model was also descriptive in nature, lacking any representation of the mechanism that accounts for the change in the velocity over time in accelerated motion. Thus the teacher decided to press students on this, requesting models that were more general in the sense that could account for any free fall situation of a ball.

IV. Discussion about their revised models

The evaluation of their revised models focused on Constantinos' revised model, although all groups had similar models. The teacher highlighted the need for improving their models to be applicable in different situations and he opened the floor for suggestions.

> Constantinos: Let's replace the number of squares [that the ball moves every machine cycle] with a number, let's say 2, that will be subtracted from the vertical [position of the ball].
> Paris: But then, it [the ball] will move always two [squares per machine cycle]
> Teacher: And so…?
> Paris: The ball will be moving with the same velocity all the time.
> Teacher: Oh, you're saying that the ball's velocity will be constant. What do we need it to be?
> Paris: Increasing…
> Teacher: Increasing! We can do what Constantinos suggested, but then the velocity will be constant…

Constantinos offered the first major revision for his model, suggesting creating a new rule in which the number of squares that the ball moves would be replaced by a rule that would subtract a number from the vertical position of the ball. According to our artifact analysis criteria, in this way, the model would include a representation of the object behavior (change in position) in a semi-causal manner, because it failed to link the velocity as a concept/variable with the change in the ball's position. However, his suggestion had a problem. Paris identified that the rule would create a simulation of a constant velocity motion and not accelerated motion. Georgia provided an idea that could help find a possible solution to this problem, and Panayiotis translated that idea into a possible model, shown in the excerpt below.

> Georgia: We can have several rules, just like the one Constantinos suggested. Each rule will have different amount subtracting from vertical.
> Teacher: And why we should do that?
> Georgia: To show that the velocity increases
> Teacher: Ok, how do we do that?
> Panayiotis: Instead of having one rule that would subtract 2 from vertical, we will create 5 rules and put them in order. The first rule will subtract 1, the second [will subtract] 2, the third will subtract] 3, then 4 and then 5.

Georgia and Panayiotis suggested returning to Constantinos model with the multiple rules (Figure 3) and revise them so that each rule would subtract a number from the ball's position. Thus, each subsequent rule would subtract a larger number from the ball's position, representing a larger velocity that was causing the accelerated motion of the ball (Figure 4). This revision, improved scientifically Constantinos proposed changes, but still failed to provide a representation of the causal mechanism that could account for the phenomenon.

In the model that Panayiotis proposed there is some representation of the increase of the velocity over time and a representation of the relation of the velocity with the change in the position. However, there is no representation of the mechanism that causes the change in velocity, which is another important part of the phenomenon under study. In order to deal with this issue, students need to identify the need for a variable that would represent velocity and then develop a rule that would cause changes in that variable. After some further discussion, Panayiotis made an additional suggestion that dealt with this issue.

> Panayiotis: I think we can replace all those rules with a single one, which it [Stagecast Creator] will run continuously. We will need a variable which will define how much the program will subtract from the vertical [position] each time. And every time, the program will increase [the value of] the variable by adding 1 to it.

Panayiotis suggested replacing all rules with a single rule that would include two subroutines (Figure 5). The first subroutine would cause changes in the position of the ball based on the value of a variable (that students called “the number to be subtracted,” but really represented velocity). The second subroutine would make changes to the value of that variable, representing in a causal manner the increase in velocity. Despite the fact that his suggestion was not in agreement with the scientifically accepted rate of velocity increase in free fall situations, Panayiotis model was the first to include a representation of the two important mechanisms underlying the phenomenon: the mechanism that underlies the change in the position and the mechanism causing the change in the ball’s velocity.

subtract 1 from vertical

subtract 2 from vertical

subtract 3 from vertical

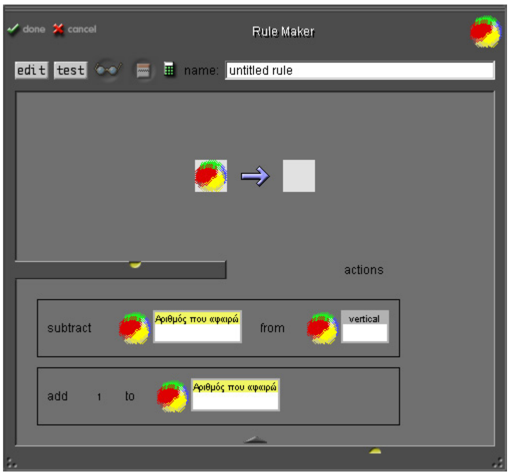
Figure 4. Panayiotis proposed model

After this, the teacher let the students return to their computers and refine their models to include representations of the mechanism causing the change in position and speed. Students spend some time on these revisions and they then presented their final models to the rest of the class.

CONCLUSIONS

In this paper we have presented a series of whole-class 5th grade student conversations that happened in the context of developing models of accelerated motion over the course of three 90-minute meetings. Our purpose was to describe the context and the content of the conversation in as much detail as possible, presenting a detailed sequential description of the modeling discourse, computer work and student-constructed models, following student work in as much detail as possible up until the development of what students thought satisfactory models of the accelerated motion.

Findings that we discussed above highlight the importance of Stagecast as a dynamic tool for developing models of physical phenomena in elementary science education and the importance of the teacher role (Louca, 2004; Louca & Zacharia, in press). The software provides students with the means and tools for constructing models as presentations of physical phenomena. Despite the evidence that we provided above, that students are able to construct models representing the causal mechanism underlying physical phenomenon, at the beginning of their work students are usually focused on how their model/simulation looks like and not whether causality is represented, thus developing descriptive models. However, when, according to the modeling-based learning approach (Constantinou, 1999), students are prompted to evaluate their models, they easily identify flaws (such as the lack of generalizability of their models or the lack of representation of casual relationships between different elements of their models), students are able to use Stagecast Creator to develop causal models of the phenomenon under study. In this sense, findings that we described above, also highlight the importance of the teacher's role in modeling, who needs to follow student discourse in as much detail as possible in order to identify, evaluate and appropriately respond to their students' thinking during modeling.



name: untitled rule

subtract Αριθμός που αφαιρώ from vertical

add 1 to Αριθμός που αφαιρώ

Figure 5. Panayiotis' final proposed model

Thus, a last important implication of this study is that such analytical descriptions of student work and thinking during authentic learning can be used as part of teacher's professional development in science, to give teachers examples of productive student thinking during scientific modeling and help them develop abilities to identify, evaluate and respond to their students' thinking.

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