Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση

Τόμ. 1 (2012)

8ο Πανελλήνιο Συνέδριο ΕΤΠΕ


# Examining the Effects of an Instructional Design Model for Teaching Pre-service Elementary Teachers to Teach Science with Computer Models

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## Abstract

In view of adequately preparing pre-service teachers to teach science through computer models, the authors herein discuss an instructional design model that was developed to guide pre-service teachers' preparation in the pedagogical uses of computer models. After the intervention, pre-service teachers were asked to propose two science topics to be taught with computer models and to design a lesson for each topic. Recommendations about how the instructional design model can be further improved in future teacher preparation programs are discussed.

**Keywords:** Computer modeling, Modeling in science, Pre-service education, Design-based research, Instructional design

## Introduction

Computer models accommodate predictions and explanations, and "incorporate something of the relation-structure of the entities represented, including the entities themselves, the properties of those entities as well as the relations among entities" (Wild, 1996, pp. 13-14). The added value of the computer is seen in the support it can provide to learners in representing and exploring the immediate consequences of their own models (Bliss, 1994; Bliss & Ogborn, 1989). According to Bliss and Ogborn (1989) there are two types of activity in computer modeling, namely, exploratory and expressive. During exploratory modeling, learners investigate models constructed by someone else, while in expressive modeling learners construct and explore their own computer models.

Unfortunately, as it is notably stated in the literature (e.g., De Jong & Van Driel, 2001; Van Driel & Verloop, 1999, 2002), pre-service teachers often lack knowledge and skill about the appropriate uses of computer models in teaching and learning. De Jong and Van Driel investigated the development of prospective science teachers' content knowledge and pedagogical content knowledge about models and modeling in the context of a postgraduate teacher education program. Surprisingly, their findings indicated that prospective science teachers, who held Master of Science degrees in chemistry, did not have pronounced knowledge about models and modeling, and that some of the important functions of models, such as making and testing predictions, were rarely mentioned by them. Crawford and Cullin (2004) also investigated the influence of instruction on prospective secondary science teachers' understanding about modeling in the context of a model-based instructional module. They reported that prospective teachers became more articulated with the language of modeling, but they did not exhibit full understanding of scientific modeling. In previous work, Valanides and Angeli (2008) discussed the design and effects of two relatively short instructional interventions of about 2.5 hours each on pre-service teachers' skills to design science lessons with models and found that despite the fact that participants developed a more articulate way to talk about models, it was evident that pre-service teachers needed more time with either learning how to use the computer modeling software, or with the process of learning how to construct a model. The findings also suggested that further research efforts were needed to explore effective ways of how to gradually support pre-service teachers in achieving higher levels of expertise in constructing scientific models, understanding their significance, and integrating them effectively in real classroom practices.

From this perspective, the purpose of this paper is two-fold. First, the authors discuss the instructional design model that was developed and implemented during a design-based research experiment in order to develop pre-service teachers' competencies to teach with computer models. Second, they discuss the results of repeated measures analyses that were employed to assess on two different occasions the effects of the intervention on participants' competencies to teach with computer models. Thus, two research questions were investigated in the study: (1) What were the effects of the instructional design model on participants' competencies to teach science with computer models in the first design task? (2) Was there a significant difference between participants' competencies to teach with computer models in the first occasion with their competencies in the second occasion?

## Method

### *Design-Based Research*

Design-based research "can help create and extend knowledge about developing, enacting, and sustaining innovative learning environments" (Design-Based Research Collective, 2003, p. 5). It bridges theory and practice and accounts for how designs function in authentic contexts by documenting successes and failures. Thus, design experiments do not focus on the summative effects of an intervention, but mostly on how "to improve the initial design by testing and revising conjectures as informed by ongoing analysis of both students' reasoning and the learning environment" (Cobb, et al., 2003, p. 11). A characteristic of design experiments is iterative design for the purpose of progressively refining the initial design. This approach of progressive refinement involves putting a first version of the design into practice to see how it works. Then, the design is changed or revised based on experience (Collins, Joseph, & Bielaczyc, 2004), until an effective and efficient design is developed.

### *Participants*

Ninety first-semester first-year pre-service elementary teachers, who were enrolled in an instructional technology course, participated in the study. The average age of the participants was 18.3 years. Pre-service teachers were required to participate in 13 whole-class (lecture) meetings and in 13 75-minute computer-lab sessions (about 30 participants in each lab). Participants had basic computing skills and were in general familiar with Word, Internet, and Powerpoint. They had no previous experience with Model-It®, the software that was used in the study, and no previous experience with constructing conceptual or computer models in order to teach science, or any other subject for that matter. All participants were also unfamiliar with basic concepts of teaching methodology.

### *The Computer Modeling Tool*

Model-It®, the computer-modeling tool that was used in the study, is a learner-centered, and an easy to use tool for constructing and testing dynamic models (Metcalf, Krajcik, & Soloway, 2000). The model construction process scaffolded by the software includes three stages. First, the learner creates the entities of the system. Second, the user creates the variables for each entity. Variables are defined as the measurable characteristics of an entity. Third, variables are designated as causal or affected, depending upon the direction of the relationship between them. Relationships are defined in terms of two orientations (i.e., increases or decreases) and different variations (i.e., about the same, a lot, a little, more and more, less and less). After the development of a model, the user can test it. Only the values of independent variables can be adjusted while the model is running.

### *The Instructional Design Model*

For the most part, traditional instructional design models are prescriptive and assume a generic and decontextualized approach to design. The model in Figure 1 diverges from traditional instructional design views, because it situates the process of instructional design in an authentic cognitive activity with real learners and teachers.

The instructional intervention (see Figure 1) consisted of five 75-minute lab sessions for a total of almost 6.5 hours. As shown in Figure 1, pre-service teachers were first asked to study the science curriculum and select a topic they considered difficult to be taught by teachers or difficult to be understood by learners. During the first lab session, pre-service teachers proposed a topic and explained why they felt the topic they proposed was difficult to be taught or difficult to be understood by learners. Then, they analyzed the underlying content systematically in terms of the scientific concepts and or principles that it entailed. Subsequently, they were asked to transform the content using appropriate representations, so that it could be better understood. Models were introduced as a form of representation. In order for pre-service teachers to better understand models and modeling, the researchers asked them to depict the growth of plants using a concept map. In doing so, they were progressively discovering the basic elements that needed to be taken into consideration in order to create the representation. Gradually, researchers introduced systems terminology, and explained that a model consisted of entities, variables, and relationships. A revised representation (model) was then constructed by the pre-service teachers that showed in more detail and in a systematic way the structure of the model in terms of its elements (i.e., entities, variables, relationships).

During the second lab session, pre-service teachers learned how to use Model-It® in order to build and test the model about the growth of plants that they constructed in the first session. The researchers also explained to the participants that the added value of computer modeling tools is paramount in systems thinking, because they provide the means for studying the influence of all independent variables on the dependent variables.

During the third lab session, pre-service teachers ran the model and controlled variables in order to test their initial hypotheses. When pre-service teachers ran the model and observed the simulated outcomes, they offered suggestions about how the model could be revised. It progressively became evident to them that their current knowledge about the phenomenon was not enough, and that they needed more information about it before revising the model. For this reason, pre-service teachers were instructed to think more about the model at home, and to present in class their revised model during the next meeting.

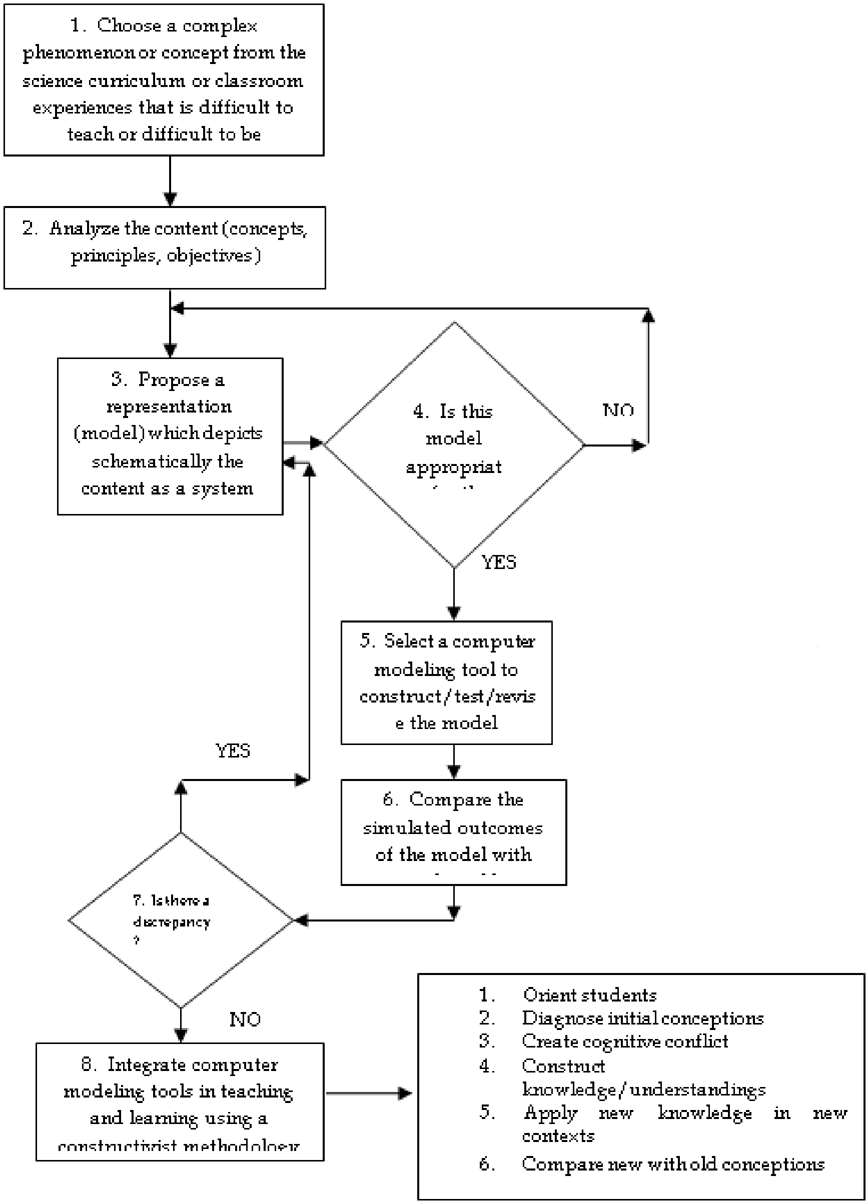


**Figure 1. An instructional design model for teaching with computer models and computer modeling tools.**

In the fourth lab session, pre-service teachers presented and defended their new models or revised models in class. During this session, pre-service teachers expressed puzzlement and skepticism about the correctness of their models, as it became evident to them that different models for the *same phenomenon* existed. This was important for the research, since it provided the spark the researchers needed in order to point out that the nature of science is tentative, and that there is not always one correct model for a phenomenon, but different tentative models based upon the knowledge that one has about the phenomenon, or what is currently known about the phenomenon.

During the fifth lab session, the researchers spent time in discussing the pedagogical uses of models in teaching and learning. Pre-service teachers were concerned that model building appears to be a difficult cognitive activity for elementary school children and indicated that they were willing to use them in sixth-grade only. Even with sixth-grade students, pre-service teachers felt that model construction would be difficult and suggested that teachers first provide students with ready-made models to explore (explorative modeling), and then gradually, as students become more familiar and comfortable with systems, teachers can move to expressive modeling where students are asked to develop their own models from scratch. The researchers stressed out that the process of model construction in the classroom should be viewed as a learning experience that involves several attempts before an acceptable model is constructed. Also during this lab session the researchers offered specific guidance as to how models can be integrated in a classroom using a constructivist methodology. Specifically, the researchers discussed in detail six events that together constituted the events of a constructivist learning sequence. These included: (a) Orient the students, (b) Diagnose initial conceptions, (c) Create cognitive conflict, (d) Construct new understandings, (e) Apply new knowledge in novel contexts, and (f) Compare new with old conceptions. Each of these events was discussed in great detail and specific examples were given for all events.

### *Assessment Task*

The researchers asked the pre-service teachers to design two sixth-grade science lessons of about 80 minutes each, in which computer models and Model-It® could be integrated for the purpose of meeting learning objectives. The first lesson was due in the 8$^{th}$ week of the semester, and the second in the 11$^{th}$ week of the semester. Between the 8$^{th}$ and 11$^{th}$ week, the researchers discussed further the added-value of different computer tools in teaching and learning, such as Inspiration, Kidspiration, and Microworlds Jr., and also provided more examples about the constructivist uses of computers in teaching and learning.

A design template was made available to assist participants in the instructional design process of designing the two lessons. Succinctly, the template included the following nine design items: (a) Select an appropriate topic to be taught with models, (b) Specify objectives, (c) Construct viable models, (d) Orient learners, (e) Diagnose initial conceptions, (f) Create cognitive conflict, (g) Construct new understandings, (h) Apply new knowledge in new contexts, and (i) Compare new with old conceptions. Pre-service teachers were specifically instructed to submit a 5-page word document addressing all nine design elements of each lesson plan. Participants' lesson plans constituted the unit of analysis. Performance on each of the nine items was assessed and a total grade for all nine elements was also calculated. Two raters, the first author of this paper and a doctoral candidate in instructional technology, rated students' performance on the nine design items. The inter-rater reliability was found to be .91.

## Results and Discussion

According to the data presented in Table 1, regarding the first design task, the average performance for each item together with the corresponding standard deviation indicated that there was still enough space for improvement, albeit in different variations, for all design items. This improvement can be easily detected from the descriptive statistics presented in Table 1 for the second design task. These results indicate that training is imperative for the development of new teaching skills, but additionally, the road to expertise is closely related with rich, systematic, and repetitive learning experiences.

**Table 1**
**Descriptive statistics of learners' performance on the two design tasks (*N* = 90)**

| | | ***Design Task I*** | | ***Design Task II*** | |
|---|---|---|---|---|---|
| | ***Design item*** | Mean | SD | Mean | SD |
| 1. | Selection of an appropriate topic | 2,47 | ,90 | 3,67 | ,60 |
| 2. | Specification of objectives | 4,35 | ,61 | 4,67 | ,44 |
| 3. | Construction of models | 3,28 | ,53 | 3,81 | ,53 |
| 4. | Student orientation | 4,02 | ,63 | 4,42 | ,49 |
| 5. | Diagnosis of initial conceptions | 4,07 | ,36 | 4,53 | ,29 |
| 6. | Creation of cognitive conflict | 2,95 | ,75 | 3,43 | ,71 |
| 7. | Construction of knowledge | 7,10 | ,72 | 8,16 | ,64 |
| 8. | Application of new knowledge | 3,43 | ,58 | 3,97 | ,56 |
| 9. | Comparison of new with old conceptions | 4,42 | 1,01 | 4,63 | ,87 |
| **Total score** | | 36,08 | 2,47 | 41,29 | 2,07 |

Pre-service teachers' performance for selecting an appropriate topic with respect to the first design task was the lowest (*Mean* = 2,47, *SD* = ,90). In general, while pre-service teachers selected appropriate topics to be taught with models, their pedagogical rationale and explanations for selecting a particular topic were poor and limited to stating that computer models were appropriate, because of the complexity of the underlying content. The researchers were more interested in well-formed arguments about the complexity of the content in connection with the affordances of Model-It®, as well as the transformation of the existing pedagogical strategies that the integration of Model-It® in a science lesson could actually bring about in a real classroom. A repeated measures analysis of variance found significant differences between participants' performance on this design item in the first and second design tasks, $F = 526{,}69$, $p < {,}01$.

With regard to the specification of objectives, pre-service teachers performed adequately in both design tasks (*Mean* = 4,35, *SD* = ,61 for the first design task; *Mean* = 4,67, *SD* = ,44 for the second design task). A repeated measures analysis of variance detected a significant difference between the first and second design tasks, $F = 153{,}73$, $p < {,}01$.

Concerning the sophistication of the models proposed, the results showed that the majority of the participants developed models with at least three entities and three variables per entity, signifying that the models pre-service teachers constructed in this study were far more complex and sophisticated than the models reported elsewhere (Valanides & Angeli, 2008). Additionally, it was evident from the difference in performance on this specific design item between the first and second design tasks, that participants' skills in developing better models improved over time (*Mean* = 3,28, *SD* = ,53 for the first design task; *Mean* = 3,28, *SD* = ,53 for the second design task). A repeated measures analysis of variance found significant differences between the first and second design tasks, $F = 1889{,}94$, $p < {,}01$.

Pre-service teachers were also very successful in thinking about creative and motivating ways to begin their lessons. Strategies for student orientation included (a) drawing students' attention to a physical phenomenon that was at the time possible to be directly experienced through the senses (i.e., seeing a rainbow), and (b) interesting and motivating role-playing scenarios. A repeated measures analysis of variance found significant effects between the first and second design tasks, $F = 356{,}00$, $p < {,}01$.

For the diagnosis of initial conceptions, participants' performance was very high on both design tasks (*Mean* = 4,07, *SD* = ,36 for the first design task; *Mean* = 4,53, *SD* = ,29 for the second design task). A repeated measures analysis of variance for this item showed significant effects between the first and second design tasks, $F = 356{,}00$, $p < {,}01$.

Participants' performance regarding the creation of cognitive conflict in their lessons was rather poor for the first design task (*Mean* = 2,95, *SD* = ,75), but after receiving feedback from the researchers, scores improved on the second design task (*Mean* = 3,43, *SD* = ,71). In essence, participants' poor performance on this specific design item could be attributed to the lack of knowledge about how to propose discrepant events in their lesson plans for the purpose of creating temporary cognitive conflict for their students. A repeated measures analysis of variance showed significant effects between the first and second design tasks on this particular design item as well, $F = 2581{,}00$, $p < {,}01$.

For knowledge construction, all participants suggested using the explorative method on both design tasks. Participants recognized that their knowledge construction strategies could have been more learner-centered. However, they explained that they chose to use the explorative method, as opposed to the expressive method, because they considered model development from scratch to be a cognitive task with a significant amount of difficulty for sixth-graders. A repeated measures analysis of variance showed that participants' scores on the second design task were significantly better than their scores on the first design task regarding this specific design element , $F = 4016{,}00$, $p < {,}01$.

Participants' performance regarding the application of new knowledge in novel contexts was satisfactory for both design tasks (*Mean* = 3,43, *SD* = ,58 for the first design task; *Mean* = 3,97, *SD* = ,56 for the second design task). A repeated measures analysis of variance showed significant effects between the first and second design tasks, $F = 1441{,}31$, $p < {,}01$.

Regarding the comparison of new with old conceptions participants' performance was also very high (*Mean* = 4,42, *SD* = 1,01 for the first design task; *Mean* = 4,63, *SD* = ,87 for the second design task). A repeated measures analysis of variance showed significant effects between the first and second design tasks, $F = 68{,}06$, $p < {,}01$.

Lastly, a repeated measures analysis of variance showed significant effects between the first and second design tasks regarding participants' total design scores, $F = 3590{,}79$, $p < {,}01$.

## Recommendations

First, in future implementations, it is recommended to address explicitly during instruction the connections among the nature of science, pedagogy, learners' difficulties, and technology, so that it becomes comprehensible to the participants how technology can be used to transform content and pedagogy in ways that signify the added value of the tool. Therefore, in future teacher preparation programs, it will be extremely beneficial if a detailed analysis of the affordances of the computer tool, in terms of how these affordances can transform both content and pedagogy is made and clearly explained. Second, it is important to differentiate instruction to address the needs of all participants in a teacher preparation program. As the standard deviations in Table 1 show, the variance in performance for each one of the nine design items varied depending upon learner knowledge, interests, and possibly time invested in completing the task. Implicitly, an issue arises here regarding the extent to which the learning objectives of an instructional intervention or program can be met by all participants at the same time and rate. The time of the instructional intervention in this study was about 6.5 hours, but according to the quantitative results of the study not all pre-service teachers reached the same level of competence in designing instructional activities. In order to address these issues, it will be useful if in future implementations of the instructional design model teachers are encouraged to also participate in virtual communities of practice in order to share and further discuss ideas with their peers at their own time.

In conclusion, the extent to which models are used in science and their potential impact on learning and understanding science, coupled with recent technological advancements that bring computer modeling into the realm of everyday activities, provide a challenge for further investigating models' potential impact on learning and understanding science. It is imperative that teacher educators undertake coordinated efforts in systematically integrating computer modeling tools in their own science courses. The findings of this study can be used as baseline data for comparison purposes in future studies that may be conducted to further validate or modify the instructional design model discussed herein.

## References

Bliss, J. (1994). From mental models to modeling. In H. Mellar, J. Bliss, R. Boohan, J. Ogborn, & C. Tompsett (Eds.), *Learning with artificial worlds: Computer based modeling in the curriculum* (pp. 27-32). London: The Falmer Press.

Bliss, J., & Ogborn, J. (1989). Tool for exploratory learning. *Journal of Computer Assisted Learning*, *5*, 1, 37-50.

Crawford, B. A., & Cullin M. J. (2004). Supporting prospective teachers' conceptions of modeling in science. *International Journal of Science Education*, *26,* 1379-1401.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R. & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9-13.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15-42.

De Jong, O., & Van Driel, J. H. (2001). *Developing pre-service teachers' content knowledge and PCK of models and modeling*. Paper presented at the National Association for Research in Science Teaching Annual Meeting, St. Louis, MO.

Design-Based Research Collective. (2003). Design-based research: an emerging paradigm for educational inquiry. *Educational Researcher, 32*, 5–8.

Metcalf, J. S., Krajcik, J., & Soloway, E. (2000). MODEL-IT®: A Design retrospective. In M. J. Jacobson & R. B. Kozma (Eds.), *Innovations in science and mathematics education* (pp. 77-115). Mahwah, NJ: Lawrence Erlbaum Associates.

Valanides, N., & Angeli, C. (2008). Learning and teaching about scientific models with a computer modeling tool. *Computers in Human Behavior*, *24*, 220-233.

Van Driel, J. H., & Verloop, N. (1999). Teachers' knowledge of models and modeling in science. *International Journal of Science Education*, *21*, 1141-1153.

Van Driel, J. H., & Verloop, N. (2002). Experienced teachers' knowledge of teaching and learning models and modelling in science education. *International Journal of Science Education*, *24*, 1255-1272.

Wild, M. (1996). Mental models and computer modelling. *Journal of Computer Assisted Learning*, *12*, 10-21.