Dialogs with Prometheus: Intelligent support for teaching mathematics

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Abstract

Dialogs with Prometheus includes an intelligent support based on natural language dialogues between the system and the user in order to feed the latter's ideas and actions back into a specific microworld. With this tool it is possible to simultaneously display on a computer screen a chat window and a microworld window, both of which are dynamically hot-linked to each other. The complex interaction between the learner and the two windows may be applied in several specialized ways like using the microworld window only as visual feedback to the chat, or by providing the learner with text feedback relevant to what he/she is doing in the microworld. For the prototypes developed so far, we have resorted to the experience of research carried out using a variety of digital learning environments. The latter, with the intention to recreate the constructionist character of actions and related learning activities that enable those settings.

Keywords

Feedback, intelligent system, dialogue window in a microworld

Feedback in digital learning environments

More than three decades of experience in researching the potential of digital environments as a favorable means for learning and teaching mathematics and sciences has shown that in order for that potential to be effective significant and sustained pedagogical support from the teacher is necessary. Yet this requirement is very difficult to meet because use of digital media fosters an exploratory attitude among students, which leads to displaying a great diversity of approaches and strategies for problem resolution or for other activities in the classroom, which in turn makes it almost impossible to have timely and specific feedback for all cases. This limitation represents one of the greatest obstacles encountered when it was time to implement models for use of digital technologies to teach mathematics and sciences, both in the classroom setting and in distance education systems (Sinclair, Arzarello, et al, 2010).

Although the majority of computer programs that are the basis for the so-called microworlds encompass, in their very design, feedback modes to help students comprehend concepts, methods or properties in mathematics or sciences, in and of itself that feedback does not always respond to the specific needs of the students at given times. This problem has been approached in recent research, as is the case of the MiGen Project of the London Knowledge Lab (http://www.lkl.ac.uk) that developed an intelligent support system in order to incorporate it into the microworld *eXpresser* –the latter was designed to help students with mathematics generalization processes. Inspired by robotics methodologies and by adaptive systems, the MiGen Project proposes a layered approach for developing an environment in which there is a

coexistence of a microworld and an intelligent system for feedback, collaboration and assessment of that same microworld (Gutiérrez-Santos, Mavrikis, & Magoulas, in press).

Dialogs with Prometheus

On the other hand, the main trait of the *Dialogs with Prometheus* tool –presented here- is that it uses intelligent support based on natural language dialogues between the system and the user in order to suggest and feed the latter's ideas and actions back into a specific microworld. *Dialogs with Prometheus* is developed with the author system *Descartes* [1] (http://recursostic.educacion.es/descartes/web/), with which it is possible to simultaneously display on a computer screen (or other digital artifact screen) an *intelligent dialogue* window and a window with a microworld or a digital interactive learning environment, both of which are dynamically hot-linked to each other. By using this tool the students can work in the micro-world on specific tasks and carry on a dialogue with the system, based on suggestions and questions raised by the latter, so that the feedback that they receive actually responds to their specific needs at a given point in their actions within a learning activity. In technological terms, the operation of both interconnected windows can be described in the following manner:

The tool *Dialogs with Prometheus* consists of two modules: CHM and MWM. CHM stands for CHat Module and MWM for MicroWorld Module. Both CHM and MWM have well defined functional behaviours and are designed to work independently of each other. However they communicate through a thin protocol consisting of only two parameters Q and A, which represent the state of CHM. Specifically, Q represents the Question or command being proposed by CHM to the learner, and A is the Answer that the learner has given (if any) to the CHM. The CHM informs the MWM of this situation and reacts accordingly by modifying its own state to fit the needs of that particular chat situation. But the MWM may receive input from the learner too, so it can decide to request the CHM to change its state and pose a different Q.

This complex interaction between the learner and the two modules may be applied in several specialized simpler ways like using the MWM only as visual feedback to the chat, or by providing the learner with text feedback relevant to what he/she is doing in the MWM. Of course, dialogs that take advantage of all different forms of communication provide a more complete educational experience. All this is miles away from mostly linearly conceived computer aided instruction. However, a word of warning is in order, *Dialogs with Prometheus* is not a simple tool for the developer of interactive learning resources. It takes a lot of effort to produce one of them, mostly because creating dialogs is, in itself, a very difficult task. We are working in trying to understand better the inner structure of dialogs as logical constructs and also in learning how to understand written responses to concrete questions and how to instruct the computer to react. There is still a lot of research to be done in this aspect. On the other hand, the creation of MWMs does not represent a problem thanks to the tool *Descartes* which is perfectly suited to create almost any MWM one could need.

Intelligent dialogues and teaching modes

In educational terms the tool was conceived to be used both in individualized feedback mode and to provide feedback on group or collaborative task activities. Its design also allows for in-class and remote education applications. In the latter respect, one should note that *Dialogs with Prometheus* work always online, and are being adapted to work on tablets and mobile phones. The way this is being done is by creating a JavaScript interpreter, taking advantage of the HTML-5 specifications, of the Descartes Runtime that was originally programmed in Java. Most of the *Descartes* functionality is already working in this new interpreter. So, *Dialogs with Prometheus* will be available very soon for tablets and mobile phones.

Since the nature of the actions that can be undertaken in this environment depend on the design of the microworld included in a given dialogue, so far, for our developments we have resorted to the outcomes from research carried out with a variety of digital learning environments, such as spreadsheets, dynamic geometry programs and Logo. Hence the intention is to recreate in the microworld window the constructionist character of actions that enable those settings. On the other hand, such a constructionist character can be enhanced due to the additional feedback that takes place in the chat window through an intelligent support, which intervenes in key episodes of the user's reasoning during a learning activity.

Types and prototypes of Dialogs with Prometheus

To date the following types of dialogues have been developed at the prototype level: 1) Learning and clarifying essential properties of geometric figures and concepts. 2) Exploring and building parameterized models of physical world phenomena. The phenomena are expressed and explored by using variation tables (spreadsheet-like), graphic representations and simulations of the phenomenon in question. 3) Intuitive exploration of discrete mathematics theorems. 4) Giving instructions to the microworld. 5) To develop other dialogues (abstract dialogue template).

The prototypes developed, pursuant to the foregoing dialogue types are (http://arquimedes.matem.unam.mx/Dialogos/): *Regular polyhedrons*: belongs to type 1 and its objective is to help the user gain a clear idea of the essential properties of polyhedrons. A fragment of dialogue is reproduced in the figure below, and depending on the user's response to a question posed by the system, the latter gives the user feedback either confirming the answer or by giving a counter-example (Figure 1). *The square*: is type 1 and its goal is to establish one single essential property of the square. Conceived as a generic example of this type of dialogue, in which the intention is for the user to discover for him/herself the essential traits of the concepts studied (Figure 2). *Environmental pollution*: belongs to type 2 and it consists of presenting a parameter-based model of the phenomenon of a lake polluted by factory waste, and for which the user explores the phenomenon by way of varying the parameters, such as the annual rate of waste (amount of pollutant flowing into the lake) and the crossing river outflow (the river crosses the lake). *Molecular diffusion*: belongs to type 2 and here the user is asked to numerically, algebraically and graphically explore a simplified version of the phenomenon of molecular diffusion in a cell with the help of a simulation window (Figure 3). *Exponential population growth*: type 2 and here the user studies population growth and the factors that modulate it due to competition or overpopulation. Several exponential-type models are explored. *Non-crossing matchings*: belongs to type 3 and with it users can create matchings (join two points using line segments) between a set of n red points and a set of n blue points. The user can intuitively describe, by way of questions posed by the system, the general result that it is always possible to find a non-crossing matching between two such sets of points (in which any red point is joined to a blue one and vice versa, without there being segments that cross each other) (Kaneko & Kano, 2003). *Logo*: type 4 and in which the user directs the movements of a turtle by giving instructions. *An abstract dialogue*: belongs to type 5 and it serves as a template to formulate other dialogues. It is made up of two files that are *Descartes* scenes: diálogo.html and micromundo.html.

Figure1. The Polyhedron

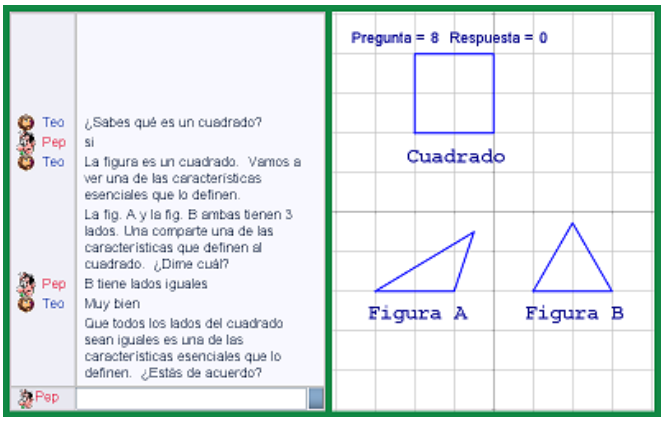

Figure 2. The Square

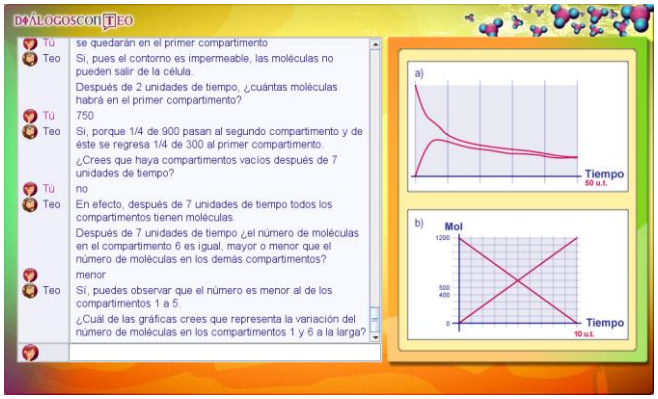

Figure 3. Diffusion in a cell.

Feedback in Dialogs with Prometheus

Intelligent feedback based on empirical studies

Design of the parameter-based modeling activities and of the specific feedback for each one is based on the findings of the testing of this type of activity with in-class students in a science classroom. The experiment, undertaken within the framework of the Anglo-Mexican Project "The role of spreadsheets within the school-based mathematical practices in sciences" [2] made it possible to identify critical modeling moments for each particular activity, moments such as prediction, model validation and model generalization moments (Molyneux, Rojano et al, 1999). Thus taking those findings into consideration, the feedback from the *intelligent* system focuses on helping the students to: check their predictions (often intuitively formulated); check their answers; and to validate and generalize their models and methods.

Intelligent Feedback based on Dialog Structure and Logical, Linguistic and Semiotic Analysis

As mentioned above, two of the most difficult aspects of Dialog development are 1) the functional structure of educational dialogs and 2) the recognition of answer patterns from actual written text. These two subjects are being investigated by a team of collaborators. The first aspect is required to organize and facilitate the development of actual dialogs. We have a data structure defined which allows their creation and development, but there is a lot to be learned yet about

how dialogs must be structured in order that they become useful learning tools. As for answer pattern recognition, a logical structure is being developed to define and specify answer patters, and a web service is already well under construction, which allows the chat module to recognize when a written text matches an expected answer pattern. This of course is vital for *Dialogs with Prometheus* to work properly, but it still requires much research and development.

Final remarks

In addition to the aspects mentioned above that are still under development, an empirical study has also begun with tertiary education students in order to test the modelling dialogues (a project funded by Conacyt, Mexico, ref. no. 168620). In the study the structure of the dialogue component and a logical linguistic and semiotic analysis will be brought together with the experience of the actual use of the dialogues so as to have the elements needed to improve upon the tool within the framework of a resourceful methodology.

Notes

[1] Descartes is an open source Authoring Tool for interactive Mathematics resources developed by the Spanish Ministry of Education, with the participation since 2009 of Instituto de Matemáticas, UNAM, and LITE, a project of ICyTDF, the Science and Technology Institute of the Mexico City Goverment.

[2] Anglo-Mexican Project developed in collaboration with the Institute of Education of the University of London and the Department of Mathematics Education of Cinvestav, Mexico, and funded by the Spencer Foundation of Chicago, Ill (Grant No. B-1493).

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