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Evaluating Resources for Scientific Modelling in a Distance Education Course

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Abstract

This research evaluates the contribution of different strategies planned for a distance education course on astronomy, designed for teachers, especially during a topic where the goal was the dynamic model of the Earth's orbit. Methodology was analysis of the written discourse of participants, collected from the virtual learning environment of the course. Using a socio-constructivist framework, we searched for elements of model usage in students' accounts on the theme, and attempted to connect this process with the resources used. Findings compare accounts and learning results from different versions of the course, when new resources were gradually inserted. Conclusions are that varied course resources can be of benefit to the pedagogical communication, providing: more precise vocabulary; better understanding of the problem; a more concrete picture to relate with; construction of elements of the solution. However, consolidation of learning happens through students-tutor interaction and this activity could not be replaced, in the course analyzed, by as varied as the resources could be. As much as our desire to make the course as flexible as possible to provide opportunity for teachers throughout the country to enroll, our results indicate that pure online interactions appear to be insufficient to teach a scientific model, as best results were only obtained when a face-to-face encounter was added to the course plan.

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Keywords: distance education; pedagogical communication; teaching scientific models; Physics and astronomy education

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1. Introduction

In distance education science courses, topics involving scientific modelling are the particularly challenging: explanations (through texts or video lectures) can be understood according to a model previously owned by the student, and this model (as theory predicts and data confirms) is frequently different from the scientific one. The solution preconized by socio-constructivist pedagogies is to foster interaction, so that models can be negotiated, departing from students' ideas and being reconstructed along the teaching process.

In distance education, the most common interaction-enabling activities are forum and chat. Both these activities were introduced in the distance course object of this research. Evaluation of the first offered class (Scarinci & Pacca, 2012) has taught us that –

- Forums can evaluate students' initial knowledge (by the questions and utterances they pose) and provide accurate and profound explanations. Unfortunately, the explanations seldom get a feedback from the student, so the tutor rarely gets to know how those explanations were understood. This happens because the student reads the answers given by the tutor, but does not feel the need to reply to it. Furthermore, not every student accesses the system on a daily basis, so a longer conversation (and meaning negotiation) via forum is seldom possible.
- Chats were found to be complementary to forums. During the chat the educator is able to monitor students' thinking point by point, as feedback is constant in synchronous interactions. On the other hand, chats tend to be more dynamic so that longer and deeper explanations are not very appropriate (also because a long explanation would place the educator in the centre of interaction, inhibiting participation of all the students). Moreover, the educator must be able (and quick) to interpret the difficulties beneath students' utterances and provide meaningful follow-up.

Authors of the course, acknowledging these characteristics, have provided course resources in order to enable and foster interactions that would construct the scientific model focused by the lessons. The immediate question that can be raised is – are these resources being effective? This research focused on part of this analysis, which is: *i)* how are interactions connected with the resources provided?; and *ii)* does learning occur? The overall purpose is to connect learning results with the resources provided.

2. Research problem and methodology

The course was on astronomy and astrophysics. There were around 30 weekly lessons (this varied a bit along the four offerings, from 2011 to 2014). Each lesson had a set of resources (such as text, video, forum, chat, questionnaire, quiz, lesson account to be analyzed, computer simulation) (fig. 1) and a virtual book that worked as a guide to explicit the purposes of each resource and suggest an order for the activities that would provide better learning. There were 5 to 10 classes of around 20 participant students, plus their tutor, who was a post-graduation student at the university that offered the course.

Investigation analyzed data from lesson 3, where the learning goal was the dynamic model of the Earth's orbit and the referential to understand that we live on its surface. Along the four years the course has been offered, the author team included new resources, after a general evaluation, from both students and tutors, that the lesson was difficult and learning results should improve. Our initial intention was to measure learning results in different years, as to make a comparison of them as new resources were provided each year. However, group profile differed from one year to the next (first year had more geography teachers, second year had mainly primary and secondary teachers and third year had a higher number of physics teachers), and tutors also changed. Therefore, it was considered that a qualitative approach could provide more meaningful elements to our analysis.

Fig. 1. Virtual learning environment showing lesson 3 and its resources, at year four.

Methodology consisted of an analysis of the (written) discourse of participants. Using a socio-constructivist framework, we searched for elements in students' accounts on the theme, in forum and chat activities and in the final answer to the lesson's assessment questionnaire. We looked for instances where participants posed a question about the content, or utterances where a student explained what he had understood. We also considered the interaction generated, from this initial question or utterance, with other students and tutor. Then we attempted to connect this process with the available resources (by seeking clues of a resource usage in the account itself and by comparing frequent elements in the accounts through the four versions of the course). This should provide an evaluation of *i)* if the student referred to a resource implicitly or explicitly when trying to explain the concept; and *ii)* if the tutor used the resource as a tool for the response. Answers to the final questionnaire were also analysed for evaluation of learning.

3. Framework

As mentioned above, we depart from the idea that learning of scientific contents is achieved by successive reconstructions of intuitive and spontaneous initial conceptions. As science is anti-intuitive (Bachelard, 1996), the initial conceptions are, by principle, different from the scientific ones. A psycho-analysis of these conceptions (and a proper treatment of errors) can, thus, be a stage of the learning process (Santos, 2005).

Learning becomes possible through interaction. Although interaction with empirical phenomena (careful observation and analysis) is very useful, once science has an experimental basis, the school learner will not achieve a formalized and accurate level without interaction with peers and teacher (the more capable partners, in Vigotskyan theory; Vigotsky, 2003). Interaction between participants of a class (educator included) is, therefore, seen as an essential element of the learning process (Gil-Pérez & Carvalho 2006).

Teaching is seen as producing a path that departs from the learner's initial knowledge and arrives at the scientific knowledge (Freire, 1996). As learners may pass through various intermediate stages (successive reconstructions), the teaching-learning process is a dialogical process, where constant feedback provides to the teacher the clues about the next step to be taken. The effort of reconstruction, though, is the learner's – this is why Vigotsky (2000) states that learning must depart from a conceptual problem (possessed by the learner), which requires a new concept to be solved.

Dialogue is effective when the teacher has a very clear arriving point and has the competence of using the tools available (learning resources) to negotiate meanings and ensure that the dialogue is being based on mutual comprehension of the terms used (Scarinci & Pacca, 2013). In distance education, the educator who elaborates the learning resources and activities (the author) is frequently not the same person who will hold the didactic contract (the tutor) – this one responsible for the interactions. The author team must be able to communicate and effectively convince the tutors about the usefulness and effectiveness of the didactic material, as well as to share the planned sequence.

4. Findings

The lesson was introduced by presenting to the students a problem – "*Why doesn't the Earth fall?*" –, whose solution would require the understanding of the new model focused. A variation of this question should be answered in written form, by the end of a week-class. The sequence included:

- A reflection about living at the surface of a sphere,
- Understanding the gravitational force as a central force,
- Explaining the orbit of the Earth and the Moon as a result of a force and a tangent velocity, and
- Concluding that the Earth *is falling* (i.e. being constantly pulled towards the Sun), but *is not falling* on the Sun due to its tangent velocity, and the composition of velocity plus gravitational force produces the orbital path.

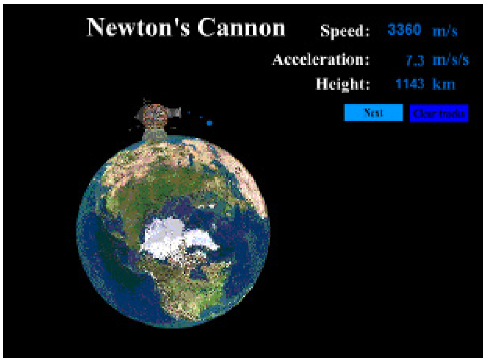
The first resources to be included in the lesson were a virtual book (interactive, exploring the question and gradually building elements for the answer by providing access do different resources) and an analogy proposal, inserted in the text, which consisted of a Newton's Cannon simulation (fig. 2a). This applet was introduced in the book with a suggestion of analysis regarding the movement of the ball (to the floor or around the Earth) depending on initial speed. Another resource included in the first version of the course was a "Lesson account" (fig. 2b), which was a transcription of an interaction of 6th grade students with their teacher on the theme. Some course participants related explicitly the text with the topic under study, as: *"I also thought that we lived in a flat part inside the Earth. (…) I realized that those children in the lesson thought like I did."*

The analogy also showed to be a powerful tool for the students: *"Hi, guys, did I understand correctly? Can the Cannon simulation be used to explain anything that orbits something else?"* (student – forum). However, tutors did not see this resource as a meaningful analogy, and in the forum/chat interactions, proposed new analogies: "*Ok, for example, imagine a sheet being held open, horizontally, with a heavy ball in the middle…"* (tutor – chat). For many students, those new analogies were inefficient and confusing.

Evaluation of the first version of the course was that the Lesson account, as well as the virtual book and the cannon simulation, were able to establish a connection of the participants with the problem, but were not sufficient to reach its solution. So students would bring their ideas and inquiries to the forum and chat, and expect to find guidance there. On the other hand, tutors were having a hard time identifying students utterances with the *origin* of their difficulties. Final answers to the questionnaire showed maintenance of alternative models, as:

> *Because the centrifugal force keeps it in equilibrium.*
> *Because it is in the orbit, the orbit keeps it in its place.*
> *Because it also has gravity...*

(a)



(b)

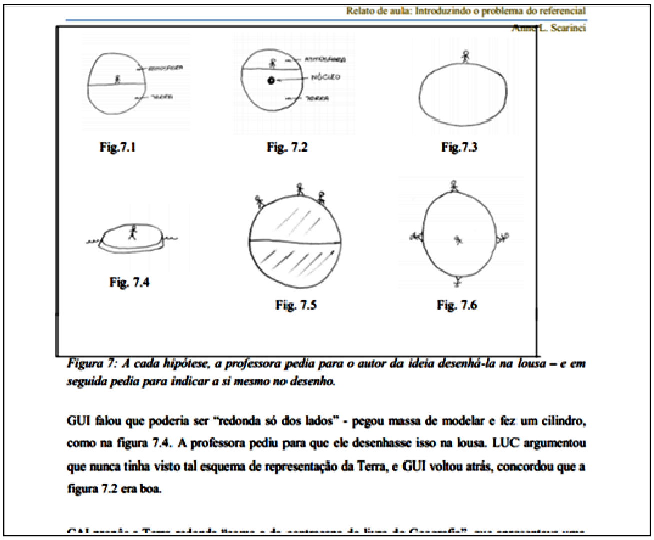


Fig. 2. (a) the applet "Newton's Cannon, used in the course; (b) an extract of the lesson account, showing the evolution of 6th graders models of "where we live on the Earth" during a class discussion.

The second version had this lesson worked in depth in tutor training. A video lecture was also included, explaining the most common conceptions on the topic and bringing a discussion about why they were wrong, highlighting the most important elements of the solution. Tutors and students profited from the video, and the training worked as to provide tutors with a better interpretation of students' alternative models. Tutors were also able to use the Newton's cannon as an analogy during the chat – although in the forum they still did not connect their explanations with the outcomes of the applet, and were not able provide meaningful feedback for students to improve their learning:

> *Student - The gravitational force is perpendicular to the energy, this energy is what maintains it in orbit and it is constant; so we say it is in equilibrium.*
> *Tutor - Your text is still confusing you have to make it better. There is not equilibrium.*

Such feedback would not help the student see how he could "make it better". To in the third version of the course, authors added a written tutors' guide including comments on some students' accounts considered typical (such as the underlying origin of the mistake, and possible teaching strategies on how to give feedback). Tutors became in fact more familiar with diagnosing students' ideas and subjacent models.

A quiz was also included, with multiple choice questions that the students would answer as many times as desired, receiving an immediate feedback with comments on why certain answer was correct or incorrect. The new resources of years 2 and 3 enhanced the usage of technical terms in the accounts (force, equilibrium, mutual attraction etc.). The students would also relate to the video pictures while trying to explain their thoughts, and use parts of the explanations of the quiz questions in the weekly assessment. Nevertheless, final answers were not completely correct and did not include all necessary elements of the model: *"The moon doesn't fall because there is the gravitational force and there isn't any other force giving it energy like with the cannon ball.*"

Students (especially those who were not physics teachers) were using the technical terms, were trying to refer to a certain model, were relating to the analogy of the Newton's Cannon, but still couldn't express themselves in an accurate way. For example, they wouldn't mention "equilibrium" anymore, but weren't able to explain why there is not equilibrium to maintain the Earth in orbit. Or, as in the example above, they wouldn't mention that "*the moon has gravity*", but they do not show clearly the gravitational force as an interaction between bodies.

The fourth version of the course brought a face-to-face encounter right after lesson 3, with a part of it dedicated to free conversation among class participants with their tutor about the subjacent model that lesson 3 focused. After this version most questionnaire answers finally improved in two ways: students were in fact considering both the inertia and the gravitational force in their explanations, and the answers were genuine, showing that the student was really reasoning with the model:

> *It's like in every moment the moon is trying to escape, but the force is pulling it back to the trajectory.*
> *Where would it fall to? Depends. If there were no velocity, it would fall to the Earth. If there were no gravitational force, it would fall to space.*

5. Conclusions

Varied course resources can indeed be of benefit to pedagogical communication, and resources added to this course provided, to tutors, an understanding of the students' alternative models, and some valuable teaching strategies to relate to them, as well as tools that could be used to facilitate explanations and interactions. To students, resources promoted:

- more precise vocabulary;
- better understanding of the problem;
- a more concrete picture to relate with;
- construction of elements of the solution.

When the objective and meaning of the resources were adequately shared with the tutor, they achieved their maximum potential as teachers. Tutor guidelines and continued education are thus a necessary and most important element of the course. As predicted, consolidation of learning, in terms of being able to apply the model in interpreting phenomena, happens through students-tutor interaction and this activity could not be replaced, in the course analyzed, by as varied as the resources could be. Once tutors were not the ones who planned the course resources, the author team must make all efforts to bring the tutors to incorporate the resources chosen, and believe in them as valuable and effective for teaching. Therefore, including specific guidelines for tutors and enhancing tutor training added a considerable gain of quality to the course, visible by learning results.

However, analysis also indicated that through online interaction only, even the most prepared tutors could not reach to all of their students. Results were considered satisfactory only when the face-to-face encounter was included. This is not the best scenario, since the purpose of a distance course is to be as flexible as possible and face-to-face encounters make it impossible for students from far away cities to participate (in Brazil, a student would have to travel as much as four thousand kilometers to attend encounters).

Though our results indicate that online interactions appear to be insufficient to teach a scientific model in this course, other hypotheses can be traced, such as the more familiarity tutors (and students) have with face to face interactions in comparison to interactions through forums and chats.

Acknowledgements

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