TEACHER EDUCATION USING COMPUTER SIMULATIONS PRE- AND IN-SERVICE PRIMARY SCHOOL TEACHER TRAINING TO TEACH SCIENCE

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ABSTRACT
The objective of this work is to study how teachers' mediation promotes the development of students' epistemic practices (EPs), in a classroom environment, using computer simulations as a didactical resource, in topics related to hydrodynamics. In particular, we want to explore what EPs occur between theory (T) and the observable-world (OW), in both pathways (from T to OW and from OW to T). We report a multi-case study with two teachers from higher education, one from an undergraduate program and another from a master's program. We use multimodal narratives (a description of what happens in the classroom, using several types of data collected inside and outside the classroom) to analyse the students' EPs and the teachers' mediation. This analysis is made using the qualitative analysis software (NVivo 8®).
The results point to that the conclusion that the differences in the occurrences and pathways found in students' EPs can be related to the different characteristics of teachers' mediation. When teachers' mediation incorporates the use CSs, there is great potential in promoting various types of students' EPs.

KEYWORDS
Computer simulation, teachers' mediation, students' epistemic practices.

INTRODUCTION

The use of computer simulations (CSs) as a complementary tool in classroom (lectures or laboratory) is referred in science education literature as particularly adequate (Khan, 2011). There is a growing interest in interactive and collaborative CS because of their potentials in constructivist learning (Richards, Barowy and Levin, 1992; Webb, 2005). CSs are good tools to improve students' hypothesis construction, graphic interpretation and prediction skills (Sahin, 2006). However this usage in classroom requires some attention regarding the teacher mediation in order to potentiate students learning (Lazonder, Hagemans and Jong, 2010).

In physical science classroom, teacher should provide epistemic support (Sandoval and Reiser, 2004) in order for students' engage on epistemic practices (EPs), which is determinant for personal knowledge construction and epistemic competences development about S&T. Through the occurrence of EPs students have real opportunities for developing the positive attitudes about science (and ways of doing it), constructing meanings associated with the practice (Jiménez-Aleixandre and Reigosa, 2006) and developing competences (Lopes, Branco and Jiménez-Aleixandre, 2011).

Teachers' mediation, through actions and languages (Lopes, Cravino, Branco, Saraiva, and Silva, 2008) can scaffold and promote the students EPs (McNeill and Krajcik, 2009), helping them connecting theories, practices and explanations of phenomena (Sandoval and Reiser, 2004). The importance of the mediating role of the teacher is well established in the research literature (Hennessy, Deaney, and Ruthven, 2005). The teacher mediates the interaction between learner and environment by selecting, changing, amplifying and interpreting objects and processes (Barton and Still, 2004; Tharp and Gallimore, 1988).

As some important science philosophers show (Bachelard, 1971; Bunge, 1973) the bridge between observable-world and theory demand both pathways: from theory to observable-world and from observable-world to theory. Data can promote a pathway towards a theoretical construction, which can be useful for many systems; with a theoretical model it is possible to better explore the phenomena, to specify its context of use, or create new artefacts.

The objective of this work is to study how teachers' mediation promotes the development of students' EPs, in a science classroom environment, using CSs. In particular, we want to explore which EPs occur in the epistemic pathway from theory (T) to the observable-world (OW), and vice-versa pathway.

We used the CS as a didactical resource to explore relationships between T and the OW in topics related to hydrodynamics. In particular, we are interested in understanding, in higher education, how these pathways are related to students' EPs (studying in pre and in-service primary school teacher training courses) and teacher didactical intentionality and orientation by presenting tasks.

METODOLOGY OF RESEARCH

Participants

This research work consists on a multi-case study (Cohen, Manion, and Morrison, 2010) involving two physical science classes from higher education: one from a masters' programme (case A) and another from an undergraduate program (case B). Each case had a different teacher that taught physics in the same higher school of education in Portugal. The main characteristics and background information about our two case studies for this qualitative research are presented in Table 1.

Table 1: Main characteristics of the two case studies

		Case	
		A	**B**
Teacher	Gender	Male	Male
	Academic Degree	PhD student of Physical Sciences Education	PhD student of Physical Sciences Education
	Teaching experience	20 years	4 years
	Research experience	14 years	6 years
Students	Age range	24 - 55	18 - 35
	Grade and Course	2nd year of a Master Programme in Science Teaching	1st year of an Undergraduate Programme in Basic Education
	Teaching experience	In-service primary school teacher	No experience
Classes	Discipline	Experimental work in Science Teaching	Physics
	Topic	Hydrodynamics – Experimental approaches	Hydrodynamics – Archimedes' Law
	Number of students	19	16
	Classroom	Physics Laboratory; space for 4 work groups, 1 computer per group	Physics Laboratory; space for 4 work groups, 1 computer per group
	Time duration	120 min	120 min

Data collection

We used multimodal narratives (MNs) as a central component of the hermeneutic unit that encompasses all types of data collected inside and outside the classroom. According to Lopes and colleagues (2010), a MN include multimodal elements such as schemas of spatial organisation of the classroom, schemes put on the blackboard by the teacher and/or by students, student reactions, explicit teachers' intentions and decisions, teachers' documents, photocopies of students' notebook, photographs of used equipment, indication of silences and gestures, print screens of CS, amongst others. The MN is a description of what happens in the classroom (Lopes, et al., 2010), based on audio recording of the lesson, using several documents and the multimodal elements obtained from the teacher, referred above. The MNs have all the same structure, which allows comparability.

Data analysis

In this study, we have analysed one MN of each teacher. Teacher mediation efforts to promote students' EPs were studied taking into account the way CS were introduced and used in class.

The process of MNs analysis was done in several steps implying different researchers, based on content analysis (Bardin, 1977; Krippendorf, 2004), and using the coding capabilities of NVivo 8®. In all steps the analysis was made by one researcher of our team, who identified and coded the parts of the multimodal narratives which contained evidences about: (a) students' EPs that took place in classroom and; (b) teachers' effort to promote students' EPs using CS as a didactical resource to explore relationships between theory and the observable-world. Then, the MNs were analysed by another two researchers, in order to validate the process. This procedure allows us to express the results with high level of reliability.

The steps of our first order data analysis, which was data driven, were the following:

- Select and code the parts of the MNs related to the pathways from OW to T and from T to OW;
- Identify and code the parts of the MNs that contain evidences about the occurrence of students' EPs. The criteria used to recognize this occurrence was the identification of students' investigative actions, in order to solve a problem or answer to a question (Sandoval, 2005). This identification was made in the previously coded pathways.

Then the coded MNs were reviewed by other researcher in order to verify if all evidences about the teachers' actions and students' EPs that took place were covered. Each category was given a name and a brief description (see table 2). In order to get an effective verification, all MN were reanalysed by other researchers (also using NVivo 8®), using the same criteria for evidences. In this verification, a 95% of agreement was obtained in categorizations made by different researchers. When any divergence in the analysis process occurred, involved researchers discuss and reflect together in order to achieve consensus about the emergent categories.

RESULTS

Teacher mediation

From MN analysis, there were differences in teachers' mediation in both cases. Namely, tasks, CSs and teachers' actions. Teachers introduced tasks and CS with different objectives.

The tasks and the CSs introduced by teacher in case A had the main objective of formalising a model that could explain the observable phenomenon of water flowing through a hole made in a bottle. In this case, teacher challenged students to find the best position to make the hole in a plastic bottle, so that the water would go as far as possible, once the bottle was placed on a table. The provided resources were two CSs available on internet: Projectile Motion – Phet; that allows predict how varying initial conditions affect a projectile path (various objects, angles, initial speed, mass, diameter, initial height, with and without air resistance) and Hydrostatic Pressure in Liquids – Fendt (the simulator allows to explore the relation between hydrostatic pressure and depth, enabling to select one of several liquids). Teacher gave autonomy to explore the CSs and followed students' work. His main task was interacting with students to reinforce their motivation, challenge students to compare the obtained results (using the CS) among them and share their point of view. Through several attempts using the CS students tried to find a model that could explain the phenomenon. The main difficulty was to understand and match the two physical concepts (Projectile Motion and Hydrostatic Pressure) with their observations with the CS.

The tasks and the two CSs introduced by teacher in case B had different characteristics: students used an existing model that allowed them to simulate different situations of the observable phenomenon of fluctuation. One CS used was Buoyancy – PhET that allows exploring how buoyancy works with blocks. In this CS, students can change the properties of the blocks and the fluid and show up arrows that represents the applied forces. The other CS used was an Excel spreadsheet simulation (Silva, 1998). By inputting data in this simulation, students could determine the minimum of potential energy of a system composed by a body in a fluid. Students could change parameters for both body and fluid (area, height, density), and see what happened to the body, fluid and system (body + fluid) in terms of potential energy. Equilibrium occurs at the minimum potential energy of the system (left graphic of Figure 1). Teacher of case B distributed a guide of activities that defined, in a general way, the dynamics of the class. The teacher followed closely students' work, asking them to explain tasks development in detail in order to motivate and engage them in the activity. The teacher gave detailed information, in particular, about the excel simulation due to its characteristics.

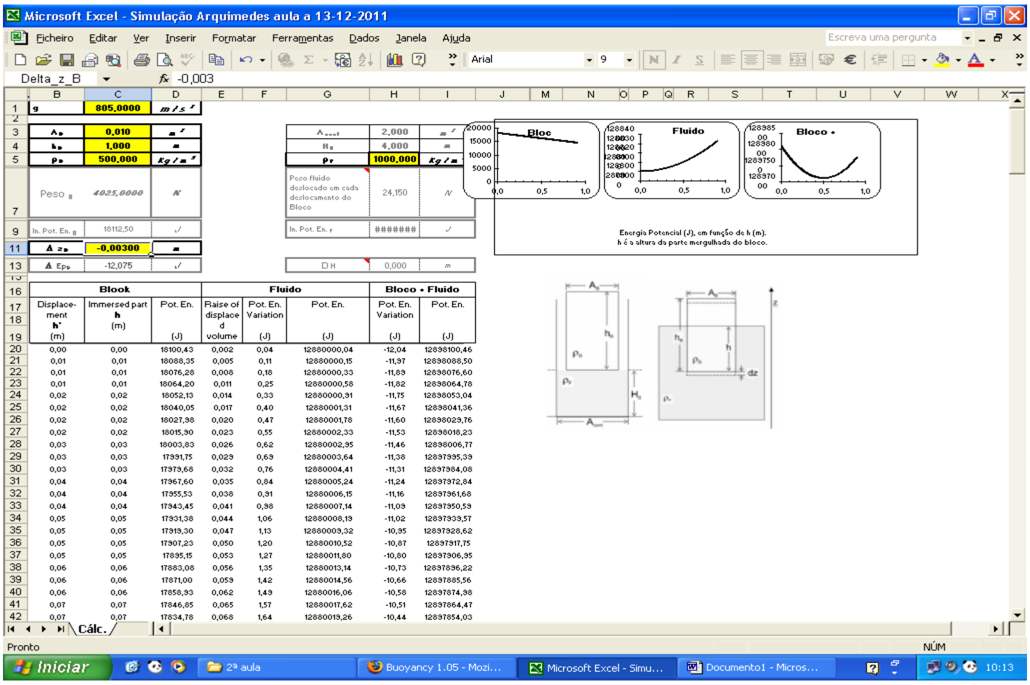


Figure 1 – Layout of the Excel simulation

Students' EP pathways

From the MNs analysis (categorization process) the identified categories for students' EPs, related with the use of CS in classroom is described in Table 2.

The total number of students' EPs occurrences in each pathway (OW-T and T-OW) and for each teacher can be seen in Table 3.

Table 2 – categories of students' EPs

Students EPs	Definition
Communicate (Comm)	Present ideas about their epistemic work
Conceptualise (C)	Make a symbolic representation of a phenomenon.
Evaluate critically (EC)	Analyse and argue, making critical evaluation of hypothesis, resources, results, used language, etc.
Formalise the model (FM)	Establish a model of a system.
Handle factually CS (HF)	Handle equipment following instructions given by teacher, or tentatively without any guiding knowledge.
Handle conceptually CS (HC)	Handle equipment guided by knowledge.
Identify empirical conditions (IEC)	Identify empirical conditions of a physical situation in which the phenomenon(a) occurs.
Interpret (I)	Interpret images, diagrams, objects, partial data, etc.
Modelling (M)	Develop a conceptualization pathway in order to construct a model of a system.
Prediction (P)	Make predictions of experimental or theoretical results based on the reasoning with knowledge.
Present information (PI)	Present information known that is relevant to the situation in use.
Present mobilising idea (PMI)	Mobilise prior knowledge to guide a possible way to solve the problem.
Questioning (Q)	Formulate questions and problems based on knowledge to obtain new understanding of phenomenon, concepts, models or to clarify terms or observations related to empirical conditions of a phenomenon.
Relate (R)	Establish relations between data variables and/or concepts in different situations.
Use symbolic mediator (USM)	Use a symbolic mediator to explain an idea that is relevant to the situation in use.
Introduce manipulable mediator (IMM)	Introduce a manipulable mediator to explain an idea that is relevant to the situation in use.

Table 3 – Total number of students' EPs occurrences

	Pathway	
	OW-T	**T-OW**
Case A	66	5
Case B	38	66

We can see that in case A most of students' EPs occur in the pathway OW-T. In case B most of the students' EPs occur in the pathway T-OW. This trend of students' epistemic pathway is according to teaching intentionality: obtain a model to explain observable phenomena – case A; use an existing model to understand how it works in different situations – case B.

Figure 2 shows the more frequent students' EPs in cases A and B in the pathway OW-T (*predicting*, *identify empirical conditions*, *questioning*, *communicate*, *relate*, *handle factually* and *modelling*) and in the other pathway T-OW (*formalise the model*, *handle conceptuall*y and *use symbolic mediator*). The students' EPs i*nterpret* occurs evenly in both pathways.

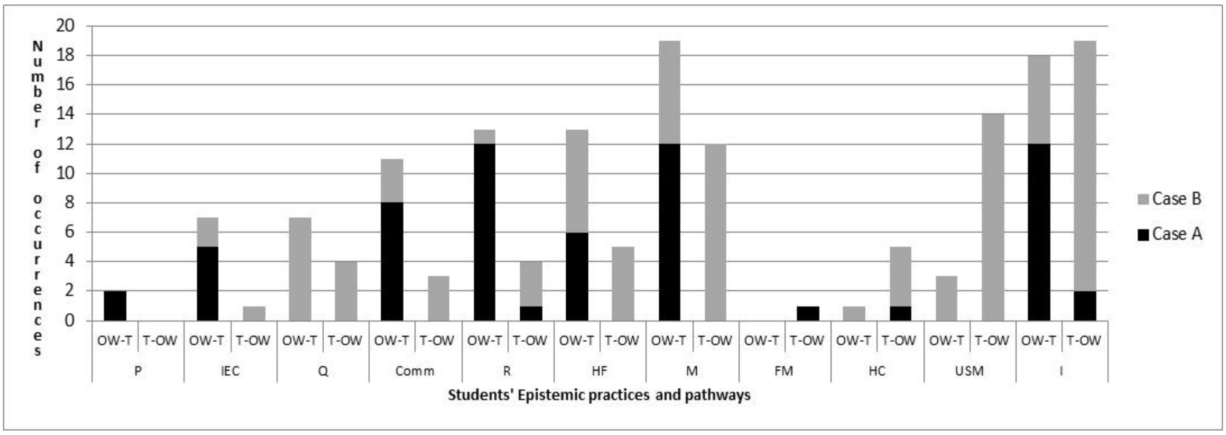
We can observe that in the OW-T pathway there is more diversity in the type of EPs than in the T-OW pathway. This can be explained by the fact that those types of EPs, like *questioning*, *predicting* and *communicate*, are relatively usual and common practices in everyday life (observable-world) phenomena.

On the other hand, *interpretation* requires support of both dimensions: theoretical and observable-world. Thus, the EP *interpret* occurs in both OW-T and T-OW pathways.

As seen in Figure 2, we can also see that there are differences in the students' EPs that occurred in both cases: some EPs occur only in one case, *e.*g.: *predicting* and *formalise the model*, that occur only in case A; *questioning* and *using symbolic mediator,* that occur only in case B.

This also can be related to the different type of mediation carried out by teachers. In case A, teacher wanted students to do some *predictions* on where to make a hole in a bottle in order to *formalise a model* that they could use in a similar situation. In case B, were it was used a model as a starting point, the first need of students was to understand how the model work. In this situation, *questioning* is an expectable attitude of students. The students' EP *use of symbolic mediator* had to do with the introduction by the teacher of graphics, tables and equations and its interpretation by students; these were the main symbolic mediators used, as the interpretation of equilibrium in terms of potential energy was made based on them.

Independently of epistemic pathway it can be verified that students' EPs *questioning*, *handle factually* or *conceptually*, *modelling*, *use symbolic mediator* and *interpret* are more frequent in students of case B than the case A. Given that in case B there was a general pathway T-OW this poses the question of the need of mobilization of theory to improve certain students' EPs. The more surprising is the *questioning*.



Legend: OW – observable world; T- Theory.

Figure 2 – Students' EPs that occur in OW-T and T-OW pathways

DISCUSSION AND CONCLUSIONS

Teachers' intentionality had large impact in students' epistemic pathway as the results shown and according to literature (Lopes, Cravino, Branco, Saraiva, and Silva, 2008; McNeill and Krajcik, 2009; Sandoval and Reiser, 2004). In spite of this general trend, the results point to the need to students have many EPs on OW-T pathway when the general epistemic pathway. Perhaps the students need having an OW reference, in order to better understand the theoretical model. When students have an OW reference (case A), most of their EPs occur in the OW-T pathway, as they are familiarized with most of the phenomena. On the other hand, when students have a T reference (case B), there is the need of getting some reference from the OW, in line with the literature (Bachelard, 1971; Bunge, 1973)

The results, limited, point to the claim that is not the type of students' EPs that made an epistemic pathway, because almost EPs are present in two cases. However: (a) there are EPs that are very important in any epistemic pathway (e.g. *questioning*, *modelling* and *interpret*); (b) there are EPs (*questioning*) that need the explicit mobilization of theory to be improved and others that will be better improved if students deal with OW (*identify empirical conditions*, *communicate* and *relate*). In the T-OW epistemic pathway the *use of symbolic mediator* is determinant to help students to have meaning in their epistemic work.

The results point to the conclusion that, when teachers' mediation incorporates the use of CSs, there is great potential in promoting various types of student's EPs. Further research will be made in order to study if this occurs with other teachers, with different tasks or different CS.

Note: The CSs used can be viewed at http://phet.colorado.edu/en/simulation/projectile-motion; http://www.walter-fendt.de/ph14e/hydrostpr.htm; http://phet.colorado.edu/en/simulation/ buoyancy

ACKNOWLEDGEMENT

We acknowledge the support of FCT for the project PTDC/CPE-CED/112303/2009, the scholarships SFRH/BD/28508/2006 and SFRH/BD/74603/2010.

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