TEACHERS' PEDAGOGICAL STRATEGIES FOR INTEGRATING MULTIMEDIA TOOLS IN SCIENCE TEACHING

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Abstract. *Since the widespread introduction of Information and Communication Technology (ICT) in education the use of multimedia environments has increased substantially. This qualitative study analyse how teachers integrate multimedia tools into teaching and learning sequences (TLS) in science education. Four in-service teachers' groups have been investigated across a 40 h teachers' training course to analyse their pedagogical strategies and difficulties for introducing multimedia tools in science teaching. During the training program to discuss multimedia environments teachers (n=14) were invited to build teaching learning sequences (TLS) about some science content using multimedia tools. The results obtained through a content analysis suggest that these teachers are integrating multimedia tools mostly to enhance particular concepts and skills (integrated approach) than to innovate presentations (enhancement approach). In all cases teachers adopted structured tasks and in two of these they were not aware of the necessity to make explicit links between the multimedia tools and the other activities. Some difficulties related to pedagogical approaches and teachers' knowledge are discussed.*

Key words: *multimedia tools, science education, teachers' knowledge, teachers' pedagogical approaches.*

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Introduction

Until a few decades ago, text has been the major mode used to teach scientific material and books have been the major teaching tool (Moreno, Mayer, Spires, & Lester, 2001). But, since scientists made microscopic phenomena visible by creating images of atoms, molecular structures, crystal formations, chemical bonding, cellules and electrical circuits, soon its use was found in science education. The use of visualizations in science and science education, especially in chemistry, has ever-increasing during the last decades. Nowadays, visualizations are a part of scientific practice that could influence science education (Linn, 2003). This author argues that visualizations can help experts to test new ideas and reveal certain aspects of scientific phenomena displaying new insights and allow comparisons with different scenarios. By other hand, visualizations are also important to students as they can illustrate an idea that words cannot describe and in the same way can introduces students to important aspects of scientific research that are frequently neglected in science education.

With the development of ICT (Information and communication technology) the use of visualizations has increase strongly, both in science and science education. The number and type of visualizations available have extended and its access became much easier. According to Moreno and Mayer (2007), it considers visualizations the non-verbal mode of represent content knowledge, which includes photos, illustrations, graphics, drawings, maps, animations, simulations and video. Throughout technology it is possible to combine verbal and non-verbal modes and create multimedia or *multimodal* (Moreno & Mayer, 2007) learning environments. These learning environments represent knowledge in to different modes (verbal and non-verbal) and frequently use two modalities: auditory and visual, i.e., through the ears and through

the eyes (Moreno & Mayer, 2007). So, textbooks are no longer the only teaching tool, computer and communication technologies are often used in science classrooms. How can teachers better integrate multimedia tools in the classroom to support students' science learning? Which is the preferable pedagogical strategy? How are they doing this? What are the main difficulties that they face in using to use these multimedia environments?

According to the recent view in science education, science teaching should put less emphasis on student acquisition of information (knowledge transmission view) and more emphasis on student understanding and use of scientific knowledge, ideas and inquiry processes (knowledge constructivist view). Osborne and Hennessy (2003) in their review also stress that the increasing use of ICT can offers modes of teaching and learning moving towards a new view on the nature of science, promoting teaching about science rather than teaching sciences contents.

Moreno and Mayer (2007) present two types of multimedia tools, the interactive and the non-interactive type. In a non-interactive type, the message is presented in a pre-determined way independent of anything the learner makes during learning; examples include an animation, video or a textbook passage with text and illustrations. In an interactive type the presented words and pictures depend on the learner's actions during learning, examples include simulations, hypermedia environments, and animation or video with pace controlled by the learner and search engine programs.

 Multimedia simulation is considered one of the most powerful applications of ICT to science at present (Hennessy, Deaney & Ruthven, 2006). This software makes possible to animate and simulate real processes (motion, biological and chemical processes) and allows learners to run "virtual experiments" that will be impossible otherwise (Hennessy, Deaney & Ruthven, 2006; Rieber, 2005). Some experiments are too complex, costly, or too dangerous to be performed in a school laboratory. This tool allows a highly interactive environment, which according to Multimedia Theory of Learning (Mayer, 2001) is the third assumption to learning occurs: the student must actively select, organize, and integrate information. The simulations allow students to visualize abstract concepts and to build mental models (internal representations) (Rapp, 2007). Nevertheless, there are some disadvantages, especially when they are used isolated they can give students the impression that every variable is easily controlled, and that reality is so simplified and all the laboratory experiments are so predictable.

Especially in chemistry classroom, multimedia animation is often used. Animations are produced as useful models at sub-micro level, depicting the structures of substances and selected chemical and physical changes (Arroio, 2012; Tasker & Dalton, 2006). Animations can show the interactive dynamic and multi-particulate nature of chemical reactions explicitly. But, according these authors they should be used and designed with careful attention in order to avoid generating or reinforce misconceptions. Sometimes it is very difficult to achieve a good scientific accuracy due to the demands of technical and computational constraints.

The video is also used in science education to present the world outside the classroom, to investigate phenomena outside the laboratory (Newton & Rogers, 2001). It allows to take students on impossible field trips, to take them around the globe, to meet new people and hear their ideas, and show experiments that cannot be done in class. The video allows more than a knowledge transmission; it allows the acquisition of all kind of experiences: knowledge, emotions, attitudes and sensations (Arroio, 2010). Video can be used in a variety of ways to enhance any lesson plan or subject. It can be used in advance to introduce a subject, to explore particular features within a subject, to promote interactivity and encourage discussion. It can also be made by students to present some research, etc.

Difficulties or "Barriers" to Introduce ICT Tools

In a review of literature, Bingimlas (2009), found several advantages of using ICT as well as several barriers to the successful integration of ICT in teaching and learning environments. ICT can assist students in their learning and help teachers enhance their pedagogical practice. Nevertheless these benefits, Bingimlas (2009), on his review also discuss the main difficulties to the integration of ICT into Education. Following the perspective of Schoepp (2005), this author calls these difficulties as "barriers", which could be defined as something that difficult the use of ICT into Education. The classification of these

barriers by researchers has not have been consensual. For instance Becta (2004) divided the barriers into categories: teacher-level barriers (individual), such as lack of time, lack of confidence, and resistance to change and in school-level barriers (institutional), such as lack of effective training in solving technical problems and lack of access to resources.

The lack of confidence is directly related with the lack of competence in integrating ICT into pedagogical practice (Becta, 2004). According to Balanskat, Blamire and Kefala (2006), teachers had a positive perception of these tools, but strategies for their effective use are still developing. This is particularly seen in VLEs (Virtual Learning Environments) which are gradually being incorporate into science education in several European countries, but it is use is still limited and more training is needed to support innovative pedagogy (Balanskat, Blamire & Kefala, 2006). Newton and Rogers (2001, p. 11) referred that experience shows that software are relevant to science education on the following purposes: *"Providing new knowledge; Revision of previous knowledge; Practice of basic skills; Collating and storing information; Presenting information; and exploring, evaluating and applying ideas."*

As, it can be seen teachers can explore technology in several ways, some of them fall into a more traditional methods (presenting information and revision of previous knowledge) and others (providing new knowledge and exploring, evaluating and applying ideas) are new ways of working, thinking and learning.

Affordances and Pedagogical Approaches to ICT Tools Use

Osborne and Hennessy (2003) stress that this tools, specially virtual environments can provide an alternative to practical work in some situations, but teachers and students do not perceived them as replacement for other activities. It is when ICT tools are integrated and balanced with other teaching and learning activities that they provide the greatest benefits. Rather than use this resources in isolation, explicit links should be made between theoretical computer models and reality, before, during and after the computer-based lesson. Also, according to this study, many teachers employ use of ICT after spending several lessons introducing and discussing some topic area. Some use multimedia technology only when it significantly enhances the activity and simpler experiments, at least, should be done in a conventional way. Others prefer all feasible experiments to be carried out manually first with subsequent use of ICT. Further, software for carrying out virtual experiments can be used for prediction and planning purposes before practical work (Walker 2002, cited in Osborn and Hennessy (2003)). In either case, teachers need to develop a balanced approach between practical work and computer methods and the complexity of this relationship is a great challenge to education.

Cox, Webb, Abbott, Blakeley, Beauchamp, & Rhodes (2003) conclude on their research report that appears to be three main approaches to ICT taken by teachers:

- ***Integrated approach***: *planning the use of ICT within the subject to enhance particular concepts and skills and improve pupils' attainment. This involves a careful and considered review of the curriculum area, selecting the appropriate ICT resource which will contribute to the aims and objectives of the curriculum and scheme of work, and then integrating that use in relevant lessons.*

- ***Enhancement approach***: *planning the use of an ICT resource which will enhance the existing topic through some aspect of the lessons and tasks. For example, using an electronic whiteboard for presenting theory about a topic. In this approach, the teacher plans to complement the lesson with an innovative presentation method to promote class discussion and the visualization of problems.*

- ***Complementary approach***: *using an ICT resource to empower the pupils' learning, for example by enabling them to improve their class work by taking notes on the computer, or by sending homework by e-mail to the teacher from home, or by word processing their homework.* Cox et al. (2003, p. 34).

According to these authors, all three approaches can enhance learning, but the effects may be different. In the integrated approach, students' learning is enhanced because it is given deeper insights into

the subject being studied and they can confront that with previous knowledge. In other words teachers change the science that they teach. In the enhancement approach, students' learning is improved because news ways of presenting knowledge are used and debates among students are promoted encouraging them to formulate their own explanations. With this approach teachers change the way that they teach science. In the complementary approach, ICT tools are used to reduce mundane and repetitive aspects of tasks such as writing essays and homework by hand, freeing the learner to focus on more challenging and subject-focused tasks. The teachers' choices are affected by a large number of key factors that goes from: their own knowledge about the subject, knowledge on ICT and access to ICT tools.

Teachers' General Knowledge and Pedagogical Approaches to Integrate Multimedia Tools in Classroom

ICT and multimedia tools are new complex resources that can provide a range of affordances that enable science learning (Webb, 2005). One key aspect of teachers' role in planning and managing learning is the skill to select the right resources for the right teaching and learning objectives (Wellington, 2002). In order to integrate this tools teachers' apply to their pedagogical content knowledge (PCK) (Shulman, 1986) together with several other categories of teachers' knowledge (content knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational context, etc) and try to make subject comprehensible to students (Webb, 2010). Nevertheless, according this author teachers need to have also knowledge how the wide range of technologies available may support the content to be taught and the best pedagogical approaches to fit the purposes. This link between content, pedagogy and technologies has been described as technological pedagogical content knowledge (TPCK) (Koeher & Mishra, 2005). So, teachers must think carefully and make some decisions before they reach the classroom in order to take advantage of using it. The pedagogical approach concerns the choice of multimedia tools to be used, its purpose, teacher controlled or hands-on use and its linking with other activities. According to Webb (2005), teachers' pedagogical strategies are a crucial component in the use of ICT in learning and teaching. The challenge is to make teachers believe not only on the affordances of these tools to improve students' learning but also they themselves have a crucial role in planning and managing this learning environments so that affordances match students' learning needs and students are able to perceive and use them (Webb, 2005). New roles for the teacher and students could arise from the use of these tools. Students could be engaged and encouraged to participate more actively in learning and teachers' role could became more focused on enabling learning through interactions rather than spend time in basic organizational and management tasks (Webb, 2010).

This study aims to analyze how fourteen Brazilian teachers, organized in four groups, that attended a training course to integrate multimedia tools in their lesson plans. It was identified their pedagogical approach and the purposes that underlie their choices. It was also discussed the teacher' general knowledge mobilized by them in order to integrate multimedia tools in their lesson plans. According to this the main research question is: What are teachers' pedagogical strategies for integrating multimedia tools in science teaching?

Methodology of Research

A qualitative research was adopted aiming to study how in-service teachers (n=14) enrolled in a teachers' training course of 40 h, integrate multimedia tools on their lessons plan. The study reported here aims to find out what kind of multimedia tools they plan to use, what pedagogical approaches they adopted for its integration and to elicit the rationale behind different choices. A case study research was adopted which is considered a preferable strategy when "how" or "why" questions are being posed (Yin, 2002).

Participants

This study was realized with fourteen science teachers from several public Brazilian schools. All participants referred that they wanted to improve their knowledge about multimedia resources in order

to introduce them in the classroom. So, they searched for this kind of training program and participated voluntarily in all the activities. They also mentioned that although in most schools there are not sufficient computers for students work in pairs, there is an increasing number of schools that has an informatics room (with few computers and a data show) where teachers can use ICT. Five teachers mentioned some pressure from the boarding school to use these tools. Due to socio economic factors they work an average of 32 h on a weekly base in class, so they have a lack of time to prepare lessons. Table 1 presents a general characterization of the teachers identified by the codes (T1, T2, etc.) in terms of graduation, subjects they taught and the length time they had been working as teachers at the beginning of this training program. It is also presented the four groups freely formed by these fourteen teachers after some training sessions, that it was named A, B, C and D.

Table 1.   General characterization of the teachers.

Group	Teacher	Graduation	Subjects	Professional time (years)
A	T 2	Biology	Nat. Sciences and Biology	4
	T 5	Chemistry	Chemistry and Nat. Sciences	18
	T 8	Biological Sciences	Nat. Sciences	6
	T 13	Biological Sciences	Nat. Sciences/ Biology	8
B	T1	Chemistry Bachelor	Chemistry	4
	T 4	Industrial Chemistry / Chemistry Teaching Graduation	Chemistry and Nat. Sciences	20
	T14	Industrial Chemistry/Chemistry Teaching Graduation	Chemistry	12
C	T 3	Chemistry Teaching Graduation	Chemistry/Physics and Maths	3
	T 7	Chemistry Teaching Graduation / Physics Teaching Graduation	Chemistry and Physics	16
	T 11	Chemistry Teaching Graduation	Chemistry	3
	T 12	Chemistry Teaching Graduation	Chemistry	8
D	T 6	Biological Sciences	Nat. Sciences	7
	T 9	Chemistry Graduation/ Pedagogy Graduation	Chemistry/Physics and Chemistry	5
	T 10	Chemistry Teaching Graduation/ Pedagogy Graduation	Chemistry	10

As it can be seen all groups were very heterogenic regarding their professional time service. Group A and D have both teachers graduated on Chemistry or Biology, and Group B and C has only teachers graduated on Chemistry. The Group C has one teacher graduated both on Chemistry and Physic. All of them are teaching natural science in elementary school.

Training Program

The training program named "The usage of multimedia tools to study high school chemistry contents" takes 40 hours was held at the Faculty of Education of the University of São Paulo in 2011 and was distributed into 10 sessions of 4 hours. The main purpose of the training program was to provide teachers with a theoretical framework mentioned on the introduction. The worked topics were:
- The use of models, images and visualization in science education, with focus on chemistry;
- Vygotsky Sociocultural Theory, Dual Coding Theory (Paivio, 1986), Cognitive Load Theory (Sweller, 1988), Multimedia Learning Theory (Mayer, 2001);

- Features of some visual tools (concrete models, 2D and 3D images, animations, simulations and molecular modelling software).

The training course exposed them to the learning theories (*sociocultural/situative* and cognitive) that can support the use of these tools, especially multimedia environments. It was also discussed the nature and role of the models in science. According to Kozma and Russell (2005), it must be considered that the use of these visualizations (external representations) could be supported by two different learning theories the *cognitive* theory and the *situative* theory. In this work authors propose the use of a *situative* theory to complement the cognitive theory of multimedia learning. The *situative* theory characterizes conceptual learning as result of social interactions. From this perspective a classroom is a community of practice where pupils are engaged in activities teacher-oriented that interact with each other and with the tools that are in the setting. The cognitive theory admits an explicit focus on the individual students' reasoning and their brain architecture (memory system etc.). Reasoning is treated as an internal mental phenomenon. From this perspective multimedia environments can support students' engagement in authentic science practices, such as asking research questions, designing investigations and planning experiments, analysing data and drawing conclusions and to support their understanding of key concepts in the domain. Several theories on this area were discussed and some visual tools were analysed according those theories. Throughout this training program teachers were invited to build in group one TLS to teach some science content (preferably on chemistry) supported by visual tools and to make an oral communication to all the class followed by a group discussion.

Instruments and Procedures

Aiming to find out some generalizability it was studied four teachers' group using multiple data sources. Each teacher group was described in order to understand the relationship between the pedagogical approaches and the specific context that they appeared. With this it is intended to identify generalisable pedagogic principles plus situational contexts (training program, teachers' background, specific school conditions, and students' background). During the training teachers were invited to build in group teaching learning sequences (TLS) about science (chemistry or natural sciences) content using multimedia tools that they could use on their classes. The researchers had no control of teachers' choices. Each teacher group made an oral communication to the class of their TLS followed by a class discussion moderated by the researcher. All the oral communications were audiovisual recorded, transcript and analysed on a later stage, as well as the TLS made by them. During this communication teachers explained some of their choices and shared some of their difficulties. At the end of the training it was realized a semi-structured interview with each group with the purpose to clarify some issues that appear during their TLS presentation. It was also used some data from field notes taken during the training program in order to characterize each teacher group.

Analysis of Collected Data

Through a content analysis it was analyzed teachers' TLS, the audiovisual record of their oral communications and the final semi-structured interview. Consistent with an interpretative orientation, the data were repeatedly examined to seek salient patterns or singularities related with the research questions. After the description of their TLS it was characterized the pedagogical approach that was used to integrate these tools. This characterization was done according the findings of Cox et al. (2003). For each multimedia tool it was identified the type of pedagogical approach based on the theoretical categories proposed by Cox et al. (2003).

Results of Research

Characteristics of Each Group and TLS Description

Group A

Group A was composed by four teachers, three of them had a degree in Biology or Biological Sciences and the fourth element had a degree in Chemistry. They all referred that they were looking for knowledge to use these resources and improve professionally: *"We cannot continue to use only traditional teaching methods; it is no longer possible (...)."* (T13). Since they all teach natural sciences, they decide to choose one content that usually they taught "Physical state changes". They build a TLS for three lessons; two will be used to work on the content and the last one to implement a modelling activity (assessment activity). They have prepared a worksheet to drive the lessons and the multimedia tools were integrated in the set of tasks. They formed an equilibrated group: one teacher (T5) with a higher teaching experience (18 years) and another teacher with high level of computer skills. The other two teachers (T2 and T8) showed basic computer skills and revealed lack of confidence. Working in group has allowed them to be comfortable in doing this planning. Beginning from de macroscopic dimension they used a concrete bottle of iced water and several images of cold fittings followed by a set of prompt questions to find students' previous knowledge about this issue and possible misconceptions. Following the worksheet they use a hydrologic water cycle animation as a whole class teaching tool. They propose a social exploration of water physical state changes. They intend to identify the water physical changes and its relationship with temperature. They use again a set of written questions to induce students' reflexion about what they discussed and observed on the animation. They assert that they use animation to make the water cycle "present" and trough them explore several issues and expand the three states of mater to other substances than water. The first lesson end with the discussion of the students' answers on the worksheet.

The second lesson begins with a set of questions guiding students to the sub microscopic dimension. The goal it is to make them think about the possible explanations "Why some substances appeared on three different states according the temperature?" On the worksheet they ask them to elaborate a theory to explain what they observe with the iced water and in the animation. This task could be done individually or in pairs. Next they use a whole class simulation "*that is a symbolic representation*" of the molecular structure. They use this tool to explore the sub microscopic world and make a bridge between the empirical world and the theoretical explanations. Once again they have on the worksheet a set of questions in order to lead students to have the opportunity to reflect and evaluate their knowledge and at the same time allow teachers to make a formative assessment.

They finish their TLS with a third lesson that will be used mainly to students work on a modelling activity, a "hands on" task. The task should be done in group, and students must build trough several materials (provided by teachers), concrete molecular models from one substance (chosen by students) on the three states of mater (solid, liquid and gaseous). The goal was to allow students to express and socialize their mental models. Each group will have the opportunity to justify their model to the class and share their ideas and thoughts about these abstract concepts. For these teachers it will be a great opportunity to access the students' mind (different formative assessment) and have the opportunity to work some misconceptions that remain. They intend to finish this class with a few more written questions provided on the worksheet, some of them taken from national exams. At last it will be explored an interactive "game" where they have to match the correct image to the text about physical state changes. They aim to invite students to perform this task on teachers' computer and project to whole class.

Group B

This group was formed by three teachers. One of them (T4) had 20 years of teaching experience and showed good computer skills, the others revealed difficulties to work with computers and the younger teacher (T1) stressed that she never used this kind of tools. All of them referred pedagogical difficulties *"I am worried, why should I use them (multimedia tools)?"* (T14). They all had a degree in Chemistry and

chose to build a TLS to teach the rate of chemical reaction using two lessons. Given that they only had one computer in the classroom they had to work with the whole class. They referred some difficulties in choosing the appropriated tools and finally they have chosen for restricted software provided by one school teacher's book editor. They said: *"We felt uncomfortable with this choice, we talked with trainer, and she said that there was no problem, it was a good opportunity to explore with the group the potentialities of the software that we supposed to use on our own classes."*

They begin the class with a teacher oral introduction to the topic and after that they planned to use a lab simulation. They justified this choice due two reasons. First they asserted that it was very important to have a previous theoretical discussion to introduce students into the topic and to "*drive the look*". Second because sometimes they did not have time to prepare practical work, they have classes with 30 to 40 students and although they believed that some practical work is important, this was a good alternative when there are no conditions to do so. They intend to use this lab simulation in an interactive way. Through this tool they want students to realize that a same reaction could have different rates. The tool allows to simulate one reaction in different conditions (temperature, concentration, pressure, etc.) in order to obtain different reaction times. They want to left students predict which conditions make the reaction faster or slower and ask them to explain their thinking. From those findings they plan to introduce the collision theory and the notion of activated complex. They stress that this concepts are very hard to teach and the students' visualization of that processes are very helpful. So, they plan to use another simulation to explain the transformations on the sub microscopic world that are according to these scientific theories. Through this tool they expect to improve students understanding of these concepts, achieve deeper learning and avoid some misconceptions. The first lesson end here with a brief synthesis of their findings.

In the second lesson they intend to discuss in detail the factors that could change a chemical rate. They use again the lab simulation, but now with another purpose. They want that students predict and explain according to the studied theories which factors can change the rate of a chemical reaction and explain them. In order to access students learning they plan to finish the lesson with a plenary where they are invited to relate these concepts with the quotidian and made a research in order to find images that fit into the studied concepts in order to build a mural.

Group C

This group was formed by four teachers. They all had a degree in Chemistry and one of them had also a graduation on physics. The most experience teachers (T7) and T11 showed good computer skills, while T3 and T12 revealed some difficulties in using technology. They choose a topic that they all used and found hard to teach. Two of these teachers will be teaching this topic in a few weeks, so they choose as the previous group to teach chemical reaction rate. They structured each lesson of the TLS on three pedagogical moments. The first one will be an "initial questioning" that begins with a teacher question/text, followed by other questions which purpose it is to engage students into a discussion about the topic to be studied. The second moment will be to "organize knowledge" supported by Power Point teacher's presentations or multimedia tools. The last moment will be to "knowledge application" where students are invited to carry out some tasks using the previous knowledge. They have planned three lessons.

So, the first lesson begins with a teacher question "Can we change the rate of a chemical reaction?" engaging students into a discussion, then they suggest to use a video with a lab experiment. As the previous group, they justified the use of the video with the difficulty to do any practical work in a 45 student's classroom. They emphasize their intention to use the video with teacher mediation, using prompting questions to engage students on its visualization. This video explores the factors that could change the chemical reaction rate. After this they intend to come back to the initial questions and make a systematisation of factors that affect the rate of a chemical reaction.

In the second lesson they plan to provide students with a scientific text about the collision theory to start the discussion about the theoretical explanations to the macroscopic visualizations that they watched on the lab video. They plan to use a Power Point presentation with this theory. After this discussion they use a simulation that represents the reactants collisions, the activated complex and the products. Through this tool they aim to explore with students the particulate nature of matter, the change on the

frequency of the collisions with several factors (temperature, concentration, catalyst, etc.). To finish this lesson they have planned to apply a test to get a formative assessment and then propose a homework student's research about food degradation. The students' research should be communicated on a Power Point presentation.

The third lesson begins with the students' presentation of their homework followed by mural construction about the topic studied.

Group D

Three teachers formed this group. One of them had a degree in Biological Sciences (T6) and the others had a degree in Chemistry. From the begging they showed some difficulties in choosing the topic and on building the TLS. They referred on the oral communication that: *"We would like to apologise, our common free time were not very well organized, and we lack competence, I assume (...)." (T10).* As Group A they decided to work on a common topic to both teachers "Physical state changes" and "Boiling and melting point". They build a TLS with 4 lessons with few details. On the first lesson they will present the contents using students' textbook. No more details about this lesson. In the second lesson after they discussed the theoretical concepts they will perform some practical demonstrations related to the students quotidian (ice cream preparation) and experimental determination of the boiling and melting point of some substances.

In the third lesson they intend to use software provided by one text book editor which had set of multimedia tools such as a lab simulation and several interactive animations (it is possible to control the pace). So, this lesson will be spent showing to students several virtual lab experiments where they can watch water boiling and melting and its relationship with temperature with a software graphic construction as the experiment is running. The software allows to try it with other substances which they considered important. For each virtual lab experiment the software had molecular animations where students could visualize the intermolecular bonding representations and the molecular model's movements as the temperature increase or decrease. They stress that is particularly important in order to make students understand the sub microscopic transformations that happen when substances are heated or cooled. The last lesson will be used to make a written assessment. Table 2 presents the four groups and the characteristics of their TLS.

Table 2.   Groups and characteristics of TLS.

Groups	Class (Year)	Science topic	Lesson number (lesson=50 min)	Multimedia tools	Mode of multimedia use	Lesson activities
A	9	Physical state changes	3	Animation; simulation; Interactive game	Projected display of both tools with whole class discussion	Individual worksheet with instructions; Whole class discussion of worksheet answers; Modelling activity
B	11	Rate of chemical reaction	2	Power Point presentation Lab experiment simulation; Molecular simulation	Projected display of both tools with whole class discussion	Topic introduction by the teacher and whole class presentation of simulations; Questions to group discussions; Plenary; Mural
C	11	Rate of chemical reaction	3	Lab experiment video; Molecular simulation	Projected display of both tools with whole class discussion	The teacher introduces the topic with pivotal questions; Use of video; Use of simulation and assessment
D	9	Boiling and melting point Physical state changes	4	Lab experiment simulation; Molecular simulation	Projected display of both tools with whole class discussion	Topic introduction by teacher; Lab experiment; Whole class presentation of simulations; Written evaluation

All four groups employed multimedia tools to teach the concepts using a *Self-regulated learning* (Hennessy, Deaney & Ruthven, 2006, p. 71). Only Group A used a *Self-regulated learning* guided by a worksheet. Due to large classes and insufficient computers, all groups planned to use the multimedia with whole class teaching. And for the same reason (too many students) the group D mentioned that they have to do lab demonstrations.

Group A had a special care into develop a TLS that started to discuss the topic from the macroscopic dimension. They mentioned that they always feel some students' learning difficulties on this curricular topic when they start to present the particulate nature of matter that explains their macroscopic observations. T5 referred: *"We are aware of students' difficulties, while we discuss physical state changes they (students) go well, but when we introduce molecular explanations they show difficulties on finding the right connections between the sub microscopic behaviour with temperature and the observables macroscopic changes".* They planned to show a concrete object and images related with students quotidian. These images are used to students retrieve some information and to begin a discussion about the chosen topic. Several questions on the worksheet guide this discussion. They mentioned they want to use different languages and stimulate students' writing: *"(...) sometimes we teachers fail, we do not encourage them enough to develop writing skills."* (T13). In order to continue to explore physical changes from students' quotidian they use an animation to present a dynamic process, i.e. to present information regarding the nature of the concept (hydrologic water cycle). They asserted that they choose this animation to highlight that all the physical changes happen at the same time, trying to eliminate some common misunderstands that students brought to the classroom, such as: first the water evaporates and condenses and then it rains and only after that it evaporate again. This allows them to begin to explore the relationship between this change and temperature, giving better insights into this subject and confront that with previous knowledge. They also wanted they (students) relate what happens in nature with what they observe for instance in an iced water bottle (quotidian). So, one could say that they are using, based on Cox et al. (2003) an *Integrated Approach,* in order to improve students' attainment on particular aspects of the topic to be taught. During the oral communication they emphasize several times the teacher's role in mediate the interactions between students and students-tool.

Following to the sub microscopic level, the simulation use will be to present students into the particulate nature of matter (providing new knowledge) (Newton & Rogers, 2001) and to allow them to visualize the motion of molecular models with temperature changes. *"This simulation allows them to see that by changing the temperature a physical state changing happens (...) and they could relate with aggregation states."* (T5) This could be considered again an integrated approach where the tool contributes to explain the particular nature of these transformations and to give students' deeper insights that words alone could not give (Linn, 2003). They also stressed that the simulation it is more interactive than animation and they intend to use this tool to explore, evaluate and apply ideas (Newton & Rogers, 2001). "*We can interact; talk, and a student or we (teachers) can touch on the computer (...)."* (T8). They considered important to introduce this issue (sub microscopic level) with this tool: *"We know that they talked about atoms and molecules on previous years and they will go on to discuss this thorough the next semester, so they have the opportunity to visualize molecular orientations and dynamic interactions for later apprenticeships"* (T8).

In the third lesson, after the modelling activity and some traditional assessment, they planned to use an interactive game (designed by them), where students could associate the image with the correct name of the transformation. They referred that they thought in students with special needs, especially the ones that have written difficulties. This tool will allow them (teachers) to have another formative assessment moment. In this case, one could say that they are using an innovative presentation to promote class interaction and allow students to practice basic computer skills. So, one can call this an *Enhancement Approach*.

Group B is planning to use two multimedia tools (both simulations) in an interactive way to allow students to have a deeper insight to the subject to be taught. In both cases they integrate this ICT tools within the subject to enhance particular concepts, selecting the appropriate tool which will

contribute to the purpose of the lesson, in what can be considered an *integrated approach*. The lab simulation seems to them a good alternative to practical work and they plan to use them for prediction. "*We can ask them (students), using questions like: What is going to be the faster reaction?*" (T4). They also stress that these virtual experiments are very practical, "*without mess*". Nevertheless they have not presented any details of how they are going to link the previous theoretical presentation with this lab simulation. The second simulation it will be to introduce new knowledge, to explore the sub microscopic world. This tool will allow students to have a better grasp of the needed conditions to "*make a chemical reaction happens (...) this simulation shows the collision theory, and what is going to happen (...) the visualization it is a big step to understanding*". (T1). In the second lesson they aim to use again the lab simulation, but now to discuss the factors that affect chemical rate. They planned to discuss all these factors running a virtual experiment to elicit each change in the chemical rate. To finish their TLS, this group intends that students build a mural. Although, this is not incorporated in technology, one can consider it as a multimedia tool used on an enhancement approach in order to promote class discussion and the visualization of images related to the studied concepts. This group provided little explanations about how they intend to make a link between the different activities of the lesson plan.

Group C referred that for several reasons it is almost impossible to use the chemical laboratory. "*In my case the school has a laboratory, but is a dump.*" (T11). So, group C have planned to use a video with a lab experiment to allow students to observe some macroscopic changes that happen during a reaction. They emphasized that they plan to do that in an interactive way, asking students to predict and explain what will going to happen. After that they planned to come back to the initial question building a link between those activities. They referred that they knew this video but they never planned to use this way. According to Cox et al. (2003), this could be considered an integrated approach given that they are planning the use of this tool within the subject to enhance a particular concept. The use of a Power Point presentation could be considered an enhancement approach to complement the lesson with an innovative presentation and promote students debate. They asserted that they have planned to use this tool presenting information to the whole class in order to make easer the social interaction.

As the previous group did they choose a simulation to present information about the particulate nature of matter, simulating through this tool the theory of collisions, using an integrated approach. The use of this simulation is done between theoretical discussions. In the last lesson they plan to invited students to present their homework using a Power Point presentation, which could be considered a complementary approach in order to allow students to improve their work. They intend to develop students' digital skills and allow them to do their own research.

Group D, after some hesitations choose to use an innovative software provided by a book editor that combined multi-representations (macroscopic, sub microscopic and symbolic) in lab simulations and in animations. Until the training program started they had doubts about the quality of the tool. They showed difficulties in building the TLS, integrate the multimedia tools and to make explicit links between all activities. They begin the TLS in a traditional way, presenting information and after that they have planned to do some practical demonstrations. In the second lesson they will use a virtual experiment, but they do not showed explicit connections between these observations and the practical demonstrations from the first lesson. This group is planning to use multimedia tools (simulation and animation) in order to allow students to have a better knowledge about the sub microscopic world of matter and make deeper connections between this dimension and the observable changes in the macroscopic world. The tools will be used in particular moments to highlight the theoretical models that predict and explain the physical changes. Given this, it can be considered that they use an integrated approach. Despite of the potentialities of this software they intend to use them mainly in a transmission style rather than a constructivist view. In Table 3 it presents a summary of the approaches that each group used.

Table 3.   The approaches used with multimedia tools.

Group	Multimedia Tool	Approach
A	Animation	Integrated approach
	Simulation	Integrated approach
	Interactive game	Enhancement approach
B	Lab simulation	Integrated approach
	Simulation	Integrated approach
	Mural	Enhancement approach
C	Video	Integrated approach
	Teacher Power Point	Enhancement approach
	Simulation	Integrated approach
	Students Power Point	Complementary approach
D	Lab simulation	Integrated approach
	Animation	Integrated approach

Discussion

As it can be seen this group of teachers used mainly an integrated approach especially to study abstract concepts related to molecular and atomic behaviours, which based on Linn (2003) it is one of the reasons to use visualizations. This kind of tools can illustrate part of the chemical concepts that words cannot. On the same way asking students to make predictions is one important aspect of scientific research that is often forgotten on chemistry classes. In all their TLS they have planned to use these tools in an interactive way with whole class teaching due to operational difficulties. According to Osborne and Hennessy (2003), with this approaches teachers are moving away from traditional views of science nature and get closer to a more constructivist view. On the other hand the complementary approach was the less used, which can be easily explained by operational difficulties both for teachers and for students (lack of skills and lack of equipments).

Enhancement approach was also used, but as it can be seen much less frequently. The lack of computer skills, the lack of equipments acts as barriers (Schoepp, 2005) to use this approach into science teaching. In order to use an innovative presentation, teachers must have a good level of confidence and competence (Becta, 2004) otherwise they will not use them. As it can be seen from our results seven teachers (50%) showed lower confidence level with ICT, which strongly acts as a barrier to integrate these tools into classroom. Also according to with Becta (2004) the lack of time will be another obstacle to introduce these resources. Considering that they had an average of 32 h on a weekly base in class, it is very difficult as they mentioned to have time to prepare a lesson with these resources.

Analysing Table 3, it can be seen that simulation was the most used multimedia tool. The teachers from our sample recognize that this tool makes possible to animate and simulate lab experiments and some abstract processes on the sub micro dimension (especially chemical processes). For our sample, given that they had a lack of time, and large classes, the use of lab simulations was seen as a good alternative to lab experiments. They recognize that it is not the ideal situation, but it is better than nothing. Also based on Newton and Rogers (2001) they recognize that they can be used to explore, evaluate and apply ideas and not only to knowledge transmission.

Some animations were used to reinforce the notion of dynamicity. For Group A, it was important for students to understand that the evaporation, condensation and solidification of water in the hydrological cycle are simultaneous, and so they chose a resource to explicit this fact. Group D also have planned to use an animation to show the dynamic, interactive and multi-particulate nature of matter (Tasker & Dalton, 2006).

The video was only used by group B. They mentioned that as they could not prepare a lab experiment and they believed that this will be the best way to substitute the practical work. Using the video with teacher mediation will be very useful to enhance students' learning. Asking them to constantly

predict the outcomes, going back and forward, will allow to create an interactive environment that it is very important to learning construction (Mayer, 2001). They asserted that the video could allow students to have a closer experience to practical work, save a lot of time and engage the whole class at the same time.

Analysing the results it can be said that these teachers tried to balance these resources with other activities, and make explicit links between theoretical computer models and reality, all those were more evident on group A and C. Group A used a worksheet to guide the lessons. They used prompt questions to engage students in discussion and requested them to give individual written answers. The goal was to develop language skills in order to be able to present an argument about some scientific phenomenon. They go from the macroscopic level to the sub microscopic level trying to make a bridge between these two levels of knowledge. At the end they propose to use a molecular modelling activity to help students to express their mental models and share them with class. This pedagogical approach fits on sociocultural (social constructivist) theories of learning which see class as community of practice. This activity will allow teachers to access students' learning and work some misconceptions that could appear. Group C also diversified their activities integrating multimedia tools in a set of tasks. They have planned to start each lesson with an "initial questioning" creating a sort of context-based environment and then use the multimedia tool to serve a specific goal. In order to reinforce the connection between the theoretical concepts to be studied and students' quotidian they ask them to make homework about food degradation. This homework will help students to contextualize their knowledge in order to make sense for them to study chemistry. In the last lesson they intend to do a plenary followed by a mural construction where they will be able to apply their knowledge.

Group B and D planned to make a theoretical introduction to the topic in a traditional way (teacher exposition), and the multimedia tools are only being used to highlight some features of chemical concepts that words cannot express (in fact Group B sometimes had a tendency to present these multimedia representations as images of reality, what could introduce several misunderstandings in students' learning). Despite this was one of the purposes of using multimedia tools it seems they do were not able to understand, according to Osborne and Hennessy (2003) that these explicit links between theoretical computer models and reality should be done before, during and after the computer-based activity. They have showed poor links between those issues. This was very clear in Group D. They could have used the lab simulation to allow students to compare their predictions with the outcomes of the lab experiments. According Webb (2005) this will be an affordance from the use of lab simulations and laboratory experiments. After using these tools, this group planned to jump into a traditional assessment activity.

Three groups (B, C and D) had opted to start by a theoretical discussion followed by a virtual or lab experience and then another multimedia activity. The group A, also opted for this alignment, but with a difference, rather than a lab or virtual experiment they used a phenomenon from students' quotidian (hydrologic water cycle). In both cases they felt the necessity to use ICT after spend some time introducing the topic. Also in either case they have planned to use the multimedia tools in an interactive way, i.e. not just to present knowledge or as a revision of previous knowledge, but to engage students in thinking and learning.

In a general way all four groups used several categories of teachers' knowledge (content knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge of educational contexts (class size, school conditions) in order to design learning experiences that take advantage of technology-mediated learning. As it can be seen they all used topics from students' school curriculum, adapted the pedagogical approaches to school and class conditions, knowledge of the learners, thinking on students' higher difficulties (abstract concepts) and according to Shulman (1986) they apply to their PCK in order to make subject comprehensible to students. This was clearer on group A and C. Both had teachers with higher teaching experience whose PCK contribute to build a structured TLS to explore all particular concepts of the topic to be taught and achieved a higher connection between them. These two groups also had at least one teacher with good computer skills who allowed them to combine this PCK with technology to create, according our point of view, better affordances for students' learning. Groups B and D and specially group D showed some failures in match TLS purposes with pedagogical approaches. One believed, based on Webb (2005), that when they use this TLS, students could not be

able to perceive and use them in a profitable way because there is an insufficient connection between all tasks.

Conclusions

This study analysed the pedagogical approaches of four teachers' groups who were enrolled in a teacher training program and built a TLS to teach some science content supported by the use of multimedia tools. It can be said that these teachers had a positive perception about these tools, given that this was the first reason to sign on for this training program. They integrated these tools with other activities although two groups (A and C) had achieved a better link between all the activities. Mainly group A, which ended their TLS with a molecular modelling activity trying to access students' mental models and an interactive game to involve all students especially those with special needs. With this innovative approach they seek to expand the links between the theoretical models and reality. All groups tried to run away from the traditional style and use these tools in an interactive way, whilst the remaining activities fit the transmission view (present information and assessment) without the necessary connection between the two. This difficulty appeared because relationship between computer methods and, for instance, practical work is complex and teachers need to develop a balanced approach (Osborne & Hennessy, 2003). These findings suggest that in order to achieve a fruitful integration between multimedia and other activities teachers must be provided with training which focuses not only on technical issues but also addresses pedagogical ones related to the role of these resources in learning, their selection, adaptation, integration and evaluation. Also combining all kinds of teachers' traditional knowledge (content, curricular, pedagogical, learners and school characteristics) with technological knowledge is necessary but not easy (Webb, 2010; Koehler & Mishra, 2005) and requires good teaching education (Rogers & Twidle, 2011). In our training course we choose to give greater emphasis to the pedagogical issues, discussing the role of these resources within sociocultural and cognitive perspectives, analysing the impact of these resources on learning and the teacher's role in these learning environments strongly supported by these tools visual. Our findings suggest that this type of training course had a positive impact since all groups referred the importance of use these tools in social interaction where the focus is on the teacher-tool-interaction. In their TLS they always try to create an environment to engage students in activities teacher-oriented. The social nature of learning and the value of collaborative activity and co-construction of understanding were strongly emphasised especially when they worked with molecular simulations. However, these observations were only evident in two of the four groups. The other two groups showed some difficulties in making a TLS with a more harmonious integration of the multimedia tools with other activities. This is probably due to the short duration of the training course and the lack of time for teachers to invest in training programs. This also highlights that the process of change requires time and conditions for teachers to work collaboratively in order to understand the role of these resources in teaching and learning.

These findings also suggest that probably the use of multimedia environments is still associated to specific contexts (in this case a training program) rather than representing the general picture in Brazilian public schools. These reinforce again the importance of training programs to promote the use of these tools on apprenticeship in a fruitful way.

In spite of the limitations of our study (number of cases) and the use of context-specific pedagogies developed for specific teaching and learning environments (Brazilian public schools) with large classes and with teachers that in general have a lack of time, one could say that the use of ICT in general may act as a catalyst for change in pedagogy. As it could be seen in these four cases it was throughout the use of multimedia tools that these teachers furthest from traditional approaches planning to use these tools mostly to engage students in a whole class discussion, nevertheless more training is needed to support innovative pedagogy. Also inquiry-based pedagogies never appeared, so more research is needed to gather a better understanding of teachers' pedagogical strategies to integrate multimedia tools in teaching and learning environments.

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