Walanda, K, Napitupulu, M and Mallaburn, A

Misconceptions sequencing the chemical processes in daniell and electrolysis cells amongst first-year science and mathematics education university students

Article

Citation (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

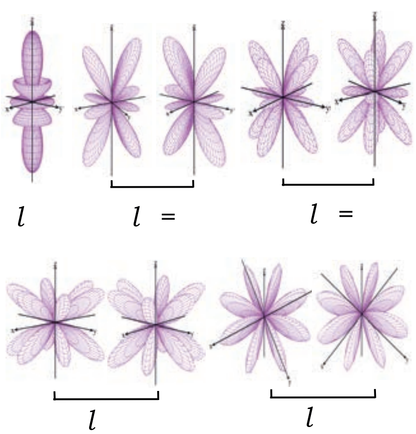
Walanda, K, Napitupulu, M and Mallaburn, A (2017) Misconceptions sequencing the chemical processes in daniell and electrolysis cells amongst first-year science and mathematics education university students. Journal of Science Education. 18 (2). pp. 113-116. ISSN 0124-5481

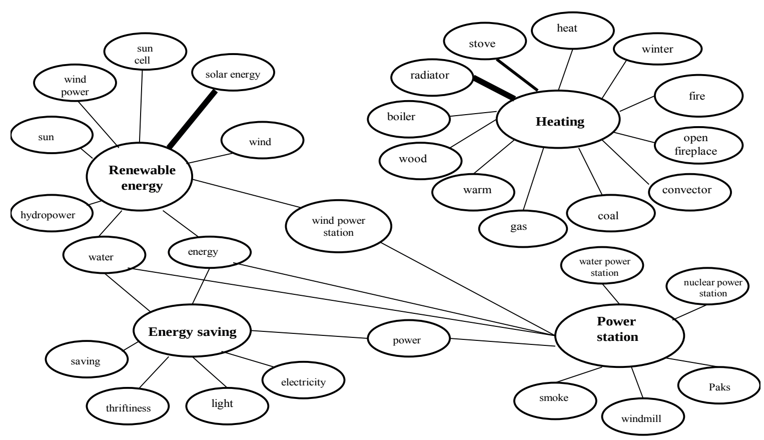
ISSN 0124-5481

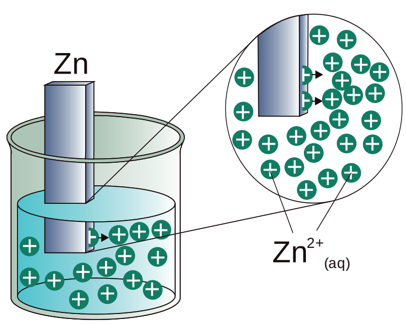
Journal of Science Education

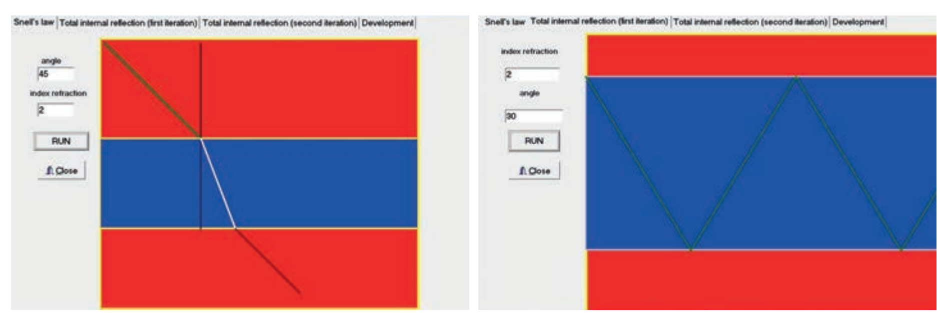
REVISTA DE EDUCACIÓN EN Ciencias

Vol. 18 n° 2, 2017









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JOURNAL OF SCIENCE EDUCATION
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ISSN 0124-5481

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JOURNAL OF SCIENCE EDUCATION, N 2, VOL. 18, 2017

CONTENTS

Model-based learning applied to natural hazards

Aprendizaje basado en modelos aplicado a los riscos naturales

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Abstract

Model-Based Learning is a methodology that promotes the restructuring of students' mental models. It includes the construction of many types of models that recreate physical phenomena, to seek the development of their scientific knowledge and scientific literacy. This work aims to analyze the opinion of 20 graduation students about the use of different types of models (computational model, physical model and mixed model) in the teaching of subjects of Natural Hazards in a public university in the north of Portugal. Having this in mind, we applied a seismological model evaluation scale, consisting of ten items classified through a five-point scale, developed and validated for this purpose. The data analysis allows us to understand that, although all the models were considered important, students recognize the major importance of a mixed model in restructuring their mental models, and in helping their learning process. Thus, the authors argue that the use of models should be more explored in science education, because they are important in the learning process, and in the promotion of students' interest and motivation in science lessons.

Key words: *geosciences, mixed models, model-based learning, science education, seismology.*

Resumen

El aprendizaje basado en modelos es una metodología que promueve la reestructuración de los modelos mentales de los estudiantes, ya que incluye la construcción de diferentes tipos de modelos que recrean los fenómenos físicos, buscando el desarrollo de sus conocimientos científicos. El objetivo del estudio es analizar la opinión de 20 estudiantes de graduación sobre el uso de diferentes tipos de modelos (modelo computacional, físico y mixto) en las asignaturas de Riscos Naturales en una universidad pública del norte de Portugal. Se aplicó una escala de evaluación de modelos de sismología, compuesta por diez artículos, desarrollada y validada para el estudio. El análisis de los datos permitió comprender que los estudiantes reconocen la importancia de todos los modelos, pero ellos consideran que el modelo mixto es el mejor en la reestructuración de sus modelos mentales, y en el desarrollo de su proceso de aprendizaje. Los autores creen que el uso de modelos debe ser más explorado en la enseñanza de las ciencias, pues son importantes en el proceso de aprendizaje, y la promoción del interés y la motivación de los estudiantes.

Palabras clave: *aprendizaje basado en modelos, educación en ciencias, geociencias, modelos mixtos, sismología.*

INTRODUCTION

Nowadays, in science education, it is contended that students develop their knowledge through the construction of mental models, which help them to develop scientific reasoning and make decisions, being the basis of individual behaviors (Jones, Ross, Lynam, Perez & Leitch, 2011). Johnson-Laird (1983) argue that mental models are internal representations of the natural world (Orlik, 1996; Moreira, 2002) that students use to interact with the world around them. The Theory of Mental Models is based on three principles: (i) mental models represent what is common to a distinct set of possibilities; (ii) mental models are iconic, their structure, as far as possible, corresponds to the structure of what they represent; (iii) they are based on descriptions and represent what is true and observable. People develop mental models to explain, perceive, and understand real world behaviors (Kurnaz & Eksi, 2015), which means that mental models are personal and constructed by individuals (Moreira, 2002), based on their life experiences, perceptions, and understandings of the world (Jones *et al.*, 2011). In fact, they are related to perceptions acquired as a result of one's actions, and an external or conceptual model can be developed by generating codes about these perceptions (Kurnaz & Eksi, 2015).

In this context, model-based learning has an important role in science education because it involves the construction of models that aim to recreate a physical phenomenon, seeking to respond to problem situations. It leads students to develop many relationships between objects and variables which can represent the scientific phenomenon and recreate its behavior (Louca, Zacharia & Constantinou, 2011). According to this methodology, the behavior of a phenomenon and its variables arises from its objects and engages students in the process of building and testing models of scientific phenomenon, and helps them to develop many important skills, such as scientific reasoning, scientific communication and argumentation (Justi & Gilbert, 2002). According to Pirnay-Dummer and his collaborators (2012), model-based learning provides a useful spur for knowledge restructuring because it induces a cognitive conflict by carefully introducing contradictory facts to those which students believe. This cognitive conflict is necessary for construction of new knowledge over their prior existing mental models (Pirnay-Dummer, Ifenthaler & Seel, 2012). Thus, model-based learning is considered fundamental in the building of students' scientific knowledge and in the promotion of scientific literacy, assuming an important role in the development of meaningful learning (Gobert *et al.*, 2011). Johnson-Laird argues that there is not only one mental model to represent a particular phenomenon, which means that there may be several, even if only one of them is scientifically consistent with it (Moreira, 1996). In this context, it is assumed that there are also many types of models that can be constructed and applied through modeling (Vasconcelos *et al.*, 2015). Many authors accept the importance of establishing a typology of models, trying to help science teachers to distinguish them and to select the best models to apply in their classroom with their students. Boulter & Buckley (2000) consider that categorizations enable groupings according to their similarities and classifications are usually constructed to highlight these similarities between types, but also to facilitate description and to reduce complexity. In fact, categorization is a crucial personal process in making sense of the world and the human mind is set upon making sense of the big range and complexity of the impressions that we are able to experience (Bailey, 1994). Categorization should allow us: (i) to structure and give coherence to the world of models and to organize the diverse range of models into a usable form; (ii) to predict patterns as we seek to fit new models into the categories; (iii) and to ask useful questions about the progression of models in the learning process and within the development of science (Boulter & Buckley, 2000).

All categorization is valid if properly justified according to the purpose of the study, and providing that it is simple and clear to be easily understood, both by teachers and students. In this work the categories of models were delineated according to their functional characteristics and three types of models were defined: computational model, physical model and mixed model.

The first model that was used was the computational model, which consists in a computer software that contains a model of a process, and is typically used to create images of phenomena, to find and test relationships in complex systems, and to test multiple hypotheses (Gilbert & Ireton, 2003). This computational model is available in the internet (Earthquakes, Make-a-Quake: Earthquake Simulator), and its manipulation was accompanied by a M*odel Exploration Document*, developed by the authors.

According to De Jong and Van Joolingen (1998), computational models can be divided into two types: simulations containing conceptual models and simulations based on operational models. The first one holds principles, concepts, and facts related to the phenomenon being simulated, such as the seismic effects on soils and buildings, as was simulated in the computational model applied in this study. The operational models include sequences of cognitive and non-cognitive operations that can be applied to the simulated phenomenon.

The use of these types of model led teachers: (i) to save time in class, allowing them to devote more time to the students rather than to the set-up and supervision of experimental equipment; (ii) to allow the manipulation of experimental variables, help the students for stating and testing hypotheses; (iii) and to provide ways to support understanding of many representations, such as diagrams and graphs (Rutten, Van Joolingen & Van Der Veen, 2012).

It is well known that students of all ages like to play with the computer, so all kinds of computational software are very interesting and helpful for teaching (Orlik, Gil, Moreno & Hernández, 2005), because they increase the students' motivation. Moreover, these types of software create a friendly learning environment while introducing and explaining some important science concepts (Orlik *et al.*, 2005). In spite of its recognized importance in improving the educational standards of science teaching, because the variety of software makes it possible improved results in instruction compared with traditional methods of education (Orlik, 1997), there is no consensus about the advantages of computational simulations because, some authors noticed that students working with these models, were unable to deal with unexpected results and that they did not utilize all the experimenting possibilities that were available. This situation stems from the lack of preparation of teachers to explore such models sufficiently with students. Thus, it is argued that the approach to the models in the classroom should be accompanied by some instructional support that helps students on a guided manipulation of the model (De Jong & Van Joolingen, 1998), and therefore it is necessary that teachers develop abilities to use computers in their classes (Orlik, 1997).

In this study it was also applied another type of model – physical model, also named material model (Chamizo, 2010). Basically, these models consist of a type of simulation used to communicate some phenomena with other individuals. Physical models express mental models that are articulated through a specific language (Chamizo, 2010), and where students directly manipulate the variables, and correspond to the regular simulations that are usually used in science education.

Physical models provide operational descriptions of physical systems (Louca & Zacharia, 2012), allowing representation of phenomena in which one or more elements of a system is changing over time, and given the dynamic character it allows students to simulate and observe a certain natural phenomenon and which variables are involved in it. Therefore it summarizes the key aspects of the theory, so that students can more easily visualize their explanatory principles (Greca & Moreira, 2001).

These types of simulations are very useful because they allow the recreation of natural phenomena that cannot be reproduced in the classroom, and help students to understand the phenomena, because they consist in concrete representations of abstract ideas in science (Louca & Zacharia, 2012). As we know, there are many natural phenomena that cannot be reproduced in the science classroom because of time and scale constraints, for example geological phenomena. Consequently, physical models are accessible for students, and teachers know that they enjoy manipulating them (Harrison & Treagust, 2000), so the application of these models stimulates students' motivation. It is suggested that teachers should be sensitive to the familiarity, similarities and differences between the models that they use to explain scientific phenomena, so they can help students to understand it and to develop their knowledge. It is also argued that students could develop the ability to produce, test and evaluate these models, as well as their dynamics, through the manipulation of physical models. Therefore they could improve their interest and have a deeper understanding of the real changes that have occurred in the course of Earth history (Deus, Bolacha, Vasconcelos & Fonseca, 2011).

Finally, we applied a different type of model named mixed model. This model includes two components: a physical component (from the physical model) and a computational component (from the computational model), so it is basically richer than the previous one, because it covers some of the characteristics of the other two models that were applied. In this study, the mixed model applied consisted in a seismic shaking table, as the physical component, which let us to simulate the earthquake in the classroom. The seismic shaking table was connected to a seismograph that recorded the propagation of seismic waves, presenting the results, trough a computer software, as seismogram (computational component).

The use of mixed models is fundamental for presenting complex concepts, because each component of the model refers to different dimensions of the same concept (Gilbert & Ireton, 2003; Vasconcelos *et al.*, 2015).

Given the particularities of Geology as a science, and taking into account the difficulties inherent to the teaching of science, as the issue of temporal and geographic scale, or the behavior of materials existing in nature, it is easy to understand the need to improve the models generally used for simulating geological phenomena (Moutinho, Moura & Vasconcelos, in press).

Boulter and Buckley (2000) suggest that learning models often require multiple components to convey information about the phenomenon, such as *animations of structures to convey behaviors, plus narration to explain the causal mechanism* (p. 46). Having this in mind, mixed models are, in fact, a type of model that articulate all the components that were needed for simulating the natural phenomenon. Considering this characteristic of mixed models, they could be assumed as an important learning strategy to help students in the construction of their scientific knowledge, because they promote the development of skills that enable students to become informed citizens and to be able to solve everyday problems.

Despite the potential of model-based learning, it requires a specific knowledge, training, and an appropriate educational context to be successful. Then, the teachers' role remains essential in the whole learning process (Libarkin & Brick, 2002), but they need to be aware so that they can develop strategies to enable the restructuring of students' mental models.

METHODOLOGY APPLIED IN THE INVESTIGATION

The purpose of the study was to analyze the opinion of graduation students about the three types of models used during the lessons about the seismic effects on soils and buildings. Each one of the three models was applied in three different classes, using Problem-Based Learning as learning strategy, because, in all classes, students were confronted with problems related to (seismic) natural hazards, that they should solve through the manipulation of the models. Hence, a scale was developed and validated, named *Seismological Models' Evaluation Scale – SMES* (Moutinho, Moura & Vasconcelos, 2014), that contained ten items that evaluate each one of the three models (computational model, physical model and mixed model) that are manipulated during the classes. In the scale, each item should be classified according to a five points scale (from 1- *Totally disagree* to 5 - *Totally agree*).

After collecting the data, they were statistically analyzed trough the 23rd version of a statistical program SPSS. In this study we used a nonparametric test and its selection was made having in consideration the dimension of the sample, which was too small to assume the normality (McDonald, 2014). It was defined a confidence level of 95% which represents a significance level of 0.05.

In this study we selected a convenience sample, which included 20 graduation students from a curricular unit of Geological Hazards, ministered in a northern Portuguese public university. The study sample contained 10 females and 10 males, with an average age of 21.6 years old and ranged 20 to 24 years old.

The samples that are defined for the statistical test are also paired, because the purpose of the study is to compare values that are different measures of an individual. As so we applied the Wilcoxon Test, a nonparametric test recommended to paired and small samples, with a non-normally distribution (McDonald, 2014).

RESULTS AND DISCUSSION

After the analysis of the data with the statistical program SPSS, the results are presented in table 1.

Table 1. Statistical information about computational, physical and mixed model (n=20).

	Computational model	Physical model	Mixed model
Average	36.2	33.9	36.4
Standard Deviation	6.70	5.15	5.92
Minimum	21	24	26
Maximum	48	45	50

According to table 1, it is possible to understand that for the study sample (n = 20), the mixed model is the one with the highest average (36.4), followed by the computer model (36.2), although this model presents the largest standard deviation value (6.70). The mixed model has a standard deviation value of 5.92, but the model with the lowest standard deviation value is the physical model (5.15). Moreover, the analysis of the data from table 1 shows that the mixed model presents higher maximum and minimum values, 50 and 26, respectively; while the computational model has the lowest minimum value (21) and the physical model has the lowest maximum value (45).

For that reason, the data analysis led us to understand that the mixed model is the one that, besides having a higher average, also has one of the smallest standard deviation values between higher maximum and minimum values. Therefore, graduation students consider that the mixed model is the best model for helping in the construction and development of the students' learning process. The other two types of models (computational and physical) have also higher average values, however these models have higher standard deviation values, which led us to consider these values not to be so precise.

Nonparametric Test – Wilcoxon Test for paired samples

As we have already referred in the methodology section, as the study sample was small and didn't have a normal distribution, it was decided to use a nonparametric test, named Wilcoxon Test. For the application of this statistical test, three hypotheses were defined (HA, HB and HC):

H0: The average scores for the computational model importance in the learning process is equal to the average scores for the importance attributed to the physical model in the learning process.

HA: The average scores for the computational model importance in the learning process is different from the ordinations average of average scores for the importance attributed to the physical model in the learning process.

H0: The average scores for the computational model importance in the learning process is equal to the average scores for the importance attributed to the mixed model in the learning process.

HB: The average scores for the computational model importance in the learning process is different from the average scores for the importance attributed to the mixed model in the learning process.

H0: The average scores for the physical model importance in the learning process is equal to the average scores for the importance attributed to the mixed model in the learning process.

HC: The average scores for the physical model importance in the learning process is different from the average scores for the importance attributed to the mixed model in the learning process.

According to the hypotheses that have been established, the Wilcoxons' nonparametric test for paired samples was applied. In this case bilateral tests were used because the data only let us ascertain whether the hypotheses are different or not, but we could not determine what is the tendency of this difference (if it exists). The results of the Wilcoxon test are organized and presented in table 2.

Table 2. Results of Wilcoxon test for the three tested hypotheses (n=20).

	HA Computational-Physical	**HB Computational-Mixed**	**HC Physical -Mixed**
Z	-1.674	-0.379	-2.094
Significance (bilateral)	0.097	0.723	0.035

It was defined a confidence level of 95% and a significance level of 0.05. The results of the Wilcoxon test (table 2) show that only the difference between the physical and the mixed model is, in fact, significant, because of the value of $p<0.05$. There is no significant improvement in the students' learning with both other types of intervention. Thus, mixed models are the best type of models to promote the construction of knowledge, which includes the restructure of students' mental models to make them more congruent with school science models.

CONCLUSIONS

This study led us to understand that graduation students recognize some importance in the application of the three types of models in geosciences lessons, because all the three types of models obtained similar average values. However, graduation students consider that mixed models are the best type of models to promote the construction of scientific knowledge, and the restructure of students' mental models.

In fact, these results led the authors to consider that because of its characteristics, mixed models are the most complete models to apply in geosciences lessons. These models have two important characteristics: first of all they have a computational component that promote the interest and motivation of students, because 21st century is the technology century, and so students are familiarized with electronic devices, such as computers. On the other hand, this type of model also has a physical component, that allows students to observe directly the phenomenon occurrence These help them to understand what happens in nature, even knowing that what they observe is only a simulation of the natural phenomenon. Therefore, the authors consider that these types of models should be more explored in science education, because they are important not only in the learning process, but also in the promotion of students' interest and motivation in science lessons. Modeling and the manipulation of models help students to develop some attitudinal skills, because they allow students to analyze problem situations, to formulate questions and to observe and understand how natural phenomena occur, and at the same time, develop scientific reasoning and argumentation skills. During this process, students understand if their mental models are consistent with the curricular model of the phenomenon and, if they are not, they naturally restructure them to make their mental models congruent with the curricular model. This process is very important because it allows students to develop a meaningful learning.

ACKNOWLEDGEMENTS

The authors acknowledge the funding provided by the Institute of Earth Sciences (ICT), under contract with FCT (Portuguese Science and Technology Foundation).

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Received 20-07-2016 /Approved 15-05-2017

Development of the learning design ability in the vocational context for pre-service chemistry teachers

Desarrollo de la capacidad de diseño de aprendizaje en el contexto profesional para los profesores de química en formación

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Abstract

Differences in the nature and purpose of learning chemistry in general schools and vocational schools have implications on the need to prepare specific capabilities for pre-service chemistry teachers. This study aims to examine the basic ability of pre-service chemistry teachers to design learning through the development of pedagogical content knowledge (PCK) in the context of vocational training. This study was designed as a descriptive study. Participants (36) in this study were students of third level on chemistry education study programs of Yogyakarta State University in Indonesia who are taking the subject of vocational chemistry. Preparation of pre-service teacher's ability was conducted through collaborative learning in small groups, class discussions and ends with an independent assignment. There are three instruments used in this study. They are assessment sheet of the ability to analyse the chemistry content appropriate in vocational context, to construct content representation (CoRe) and to construct pre-pedagogical and professional experience repertoires (p-Pap-eRs). The results showed that pre-service chemistry teachers have a pretty good ability in designing chemistry learning in vocational context. The main implication of this research is the need for restructuring of the curriculum for pre-service chemistry teacher education programs that are more concerned with professional development in the context of vocational schools.

Key words: *learning design, Content Representation , Pedagogical and Professional experience Repertoires , vocational, chemistry teacher, Pedagogical Content Knowledge.*

Resumen

Las diferencias en la naturaleza y la finalidad del aprendizaje de la química en las escuelas, tienen implicaciones sobre la necesidad de preparar los profesores de química con las capacidades específicas. Este estudio tiene como objetivo examinar la capacidad básica de licenciados de química para diseñar el aprendizaje a través del desarrollo del conocimiento didáctico del contenido en el contexto de la formación profesional. Los participantes (36) de este estudio eran estudiantes de tercer nivel sobre programas de educación de la química de la Universidad Estatal de Yogyakarta en Indonesia. El trabajo se llevó a cabo a través del aprendizaje colaborativo en grupos pequeños, discusiones en clase y terminó con una asignación independiente. Los tres instrumentos fueron : la hoja de evaluación de la capacidad de analizar el contenido de la química apropiada en el contexto profesional, para la construcción de la representación del contenido y para la construcción de repertorios de experiencia pre-pedagógicos y profesional. El resultado mostró que los licenciados de química tienen una buena capacidad de aprendizaje en el diseño del curso de química en el contexto profesional. La implicación principal de esta investigación es la necesidad de una reestructuración del plan de estudios de licenciatura en la dirección del desarrollo profesional en el contexto de las escuelas de formación profesional.

Palabras clave: *diseño de aprendizaje, representación de contenido, experiencias pre-pedagógicas y profesionales , profesor de química, conocimiento didáctico del contenido .*

INTRODUCTION

One of the capabilities that are important for the teacher's role as controller of learning in the classroom is the ability to design learning. Learning design is very important because it is used as a guide for teachers in implementing the learning to achieve the expected goals. In particular, a pre-service chemistry teacher at a vocational school must have a good ability to develop learning chemistry in accordance with the vocational context. There are two things that are associated with the ability of pre-service teachers in designing learning. Both of these are a foundation of knowledge and thinking framework for teachers in designing learning in order to create a wide variety of learning conditions conducive to facilitate student learning.The development of foundation of knowledge and thinking framework forteachers in designing learning begins with constructing Pedagogical Content Knowledge (PCK) for pre-service chemistry teachers. PCK as a construct of teachers' knowledge is subject and domain-specific (Shulman, 1986; Shulman, 1987, Bucat, 2004). PCK is an amalgamation of content and pedagogy in a specific context (Gess-Newsome, 1999). In other words, it refers to knowledge about teaching and learning of particular subject matter that takes into account the particular learning demands inherent in the subject matter (Bucat, 2004). According to Magnusson et al. (1999), components of PCK include orientation of teaching science (related to the subject matter), knowledge of the science curriculum, knowledge of learning strategies, knowledge of assessment and knowledge about the students' understanding of science. So, while learning "how" to teach chemistry, teachers should develop sound knowledge of chemistry concepts and principles, as well as appropriate strategies for specific chemistry topics and where the topics be taught.

Loughran et al. (2006) developed a model representation of the PCK of a teacher in two forms of documents, namely Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs). Both of documents make explicit the different dimensions of, and links between, knowledge of content, teaching, and learning about a particular topic. The CoRe attempts to portray holistic overviews of expert teachers' PCK related to the teaching of a particular topic. They contain a set of enduring ideas about a particular topic at the head of the columns and a set of pedagogical questions for each row. PaP-eRs is a narrative that describes how the content is presented. CoRe has been used successfully in pre-service science teacher education to help novice teachers understand what PCK might involve and to develop their own representations of teaching in particular topic areas. In the study by Loughran et al. (2008), a pre-service educator invited student teachers to construct their own examples of CoRe after they had examined and reflected on those created by expert teachers. The findings from this study strongly suggest that the focus on PCK using CoRe to frame their thinking about the links between science content and pedagogy did help the student teachers to gain a more sophisticated view about learning to teach science and how to teach for understanding. Another study along similar lines also sought to promote science student teachers' PCK through CoRe design (Hume & Berry, 2011). The results showed that the training in constructing CoRe, followed by proper scaffolding, allows the development of PCK in novice teachers The pre-service teachers found the task challenging, and their lack of classroom experience and experimentation proved to be a limiting factor in being able to develop CoRe successfully.

Differences in the nature and purpose of learning chemistry in general schools and vocational schools have implications for the need to prepare specific capabilities for pre-service chemistry teachers. This study aims to prepare the basic ability of pre-service chemistry teachers to design learning through the development of PCK in the context of vocational education. The abilities of pre-service teachers examined include the ability to analyse the chemistry content in vocational context, the ability of constructing chemistry CoRe in vocational context and constructing p-PaP-eRs in the vocational context . The meaning of p is predictive that shows that what is described in the PaP-eRs places more emphasis on pre-service chemistry teachers' ideas before implementing learning. The third capability became the foundation for developing a chemistry learning that is in accordance with vocational context.

METHODOLOGY

Research design and subject

This study was designed as a descriptive study of pre-service chemistry teachers' ability to design learning in a vocational context . Participants in this study were students of third level on chemistry education study programs of Yogyakarta State University in Indonesia who are taking the subject of vocational chemistry. There are 36 students who participated in this study.

Setting of learning

Preparation of pre-service teacher's ability was conducted through collaborative learning in small groups, class discussions and ends with an independent assignment. Stage of learning undertaken includes:

Collaborate in small groups (4-5 pre-service chemistry teachers) to elaborate the Chemistry Basic Competence (BC-C) in the national curriculum into content that can be taught in vocational school. Next, pre-service teachers collaborate in groups to analyse documents of -basic competencies of vocational subjects -(BC-V) on the Automotive Engineering program, choosing the BC-V that require a basic understanding of chemistry concepts and integrate it with chemistry content. The end product of this stage is the matrix of chemistry content in vocational context of automotive engineering which compiled independently by pre-service chemistry teachers.

Collaborate in the group to discuss the theory of PCK and practice of constructing CoRe of chemistry in the vocational context of automotive engineering. Furthermore, each of pre-service chemistry teacher constructing a CoRe chemistry in vocational context for the petroleum topic.

Collaborate in the group to discuss the theory to construct of PaP-eRs. Furthermore, each prospective teachers constructing the p-PaP-eRs chemistry in vocational context for a particular concept in petroleum topics. Some examples of concepts taken are the quality of gasoline, the combustion of petroleum fuels and alternative fuels.

Research instruments

There are three instruments used in this study. **First**, the assessment sheets of the ability to analyse the chemistry content appropriate in the vocational context. The preparations of these instruments were developed based on the capabilities needed by teachers to determine the essential concept to be taught in vocational schools according to students' needs. There are two aspects were assessed namely the ability to analyse BC-C and to integrate BC-C with BC-V. The ability to analyse BC-C is developed into three indicators related to the ability of pre-service teachers in describing BC-C and identifies the essential concept. While the second aspect is developed into four indicators related to the ability to choose the BC-V related to chemistry learning, choosing BC-C suitable with vocational context and develop chemistry content of vocational context.

Second, the assessment sheets of the ability to construct CoRe. The indicators of ability assessment to construct CoRe ability are developed by reference to the questions in the preparation of CoRe according to Loughran (2006) and added the questions related to the accuracy in selecting the main ideas on a topic that will be taught according to the vocational context. Thus there are nine indicators of assessment of ability in constructing CoRe.

Third, the assessment sheets of the ability to construct p-Pap-eRs. Assessment indicators to assess the ability of prospective teachers in constructing p-PaP-eRs adapted based on analysis of p-PaP-eRs according to Mulhall et.al. (2004) with an emphasis on the didactic aspect to anticipate situations that may be occur in learning. There are six assessment indicators, namely the ability to formulate objectives, analysis of the difficulties in the content teaching, accuracy of learning strategy selection, the depiction of the interaction of teachers and students, the anticipation of difficulties in learning and how to ensure students understanding.

Assessment rubrics are developed for the three instruments as guidance in scoring. Scores given are 5,4,3,2, and 1

Data Analysis Techniques

The data are obtained from the assessment results of the chemistry content matrix in vocational context, chemistry CoRe in vocational context and p-PaP-eRs in vocational contexts compiled by pre-service teachers. Descriptive analysis was used to determine the ability achievement of pre-service chemistry teacher. The Percentage of achievement every aspect of designing learning ability is examined by dividing the score obtained with the ideal score. Furthermore, the average percentage of achievement is categorized into five criteria. Very good criteria for the percentage range 81-100, good for 71-80, sufficient for 56-70, less well for 41- 55 and much less to the percentage of less than 55.

RESULTS AND DISCUSSION

Results

Ability to design learning in this study is intended as the ability to develop a foundation of knowledge and framework thinking teachers who are started from the content knowledge to be used as a guide to create a lesson plan that will be implemented in the classroom.

The ability of pre-service teacher's to analyse the chemistry content in vocational context.

Based on the results obtained by analysis of mean score capability to analyse the chemistry content that achieved pre-service teachers after the learning is amounted to 25.36 and is included in good criteria. The highest scores obtained by pre-service teachers is 30 or 85.7% of the maximum achievement. The lowest score achieved is 18 with the level of achievement only of 51.43%. Figure 1 presents an overview of the distribution of criteria for the achievement of the ability to analyse the chemistry content in vocational context by pre-service teachers. The largest percentage (41.6%) of achievement the ability of pre-service chemistry teacher's to analyse the chemistry content in the vocational context is in category pretty good.

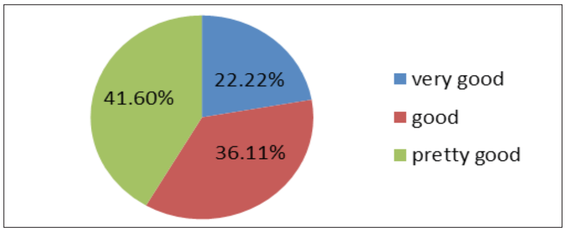

Figure 1. The distribution of criteria for the ability to analyze the chemistry content of vocational context overall

For a further look at the ability of pre-service teachers, the data were also analyse for each aspect of ability. The mean score obtained to aspects of the analyse BC-C is 13.25 with very good criteria. Distribution of criteria pre-service teacher's ability is presented in Figure 2.

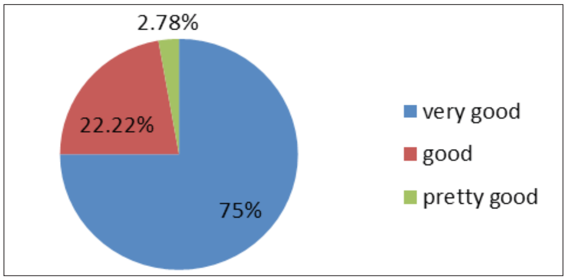

Figure 2. The distribution of criteria for the ability aspect of analyzing BC-C

The second aspect is the ability to integrate BC-C with BC-V that described in four indicators. The mean scores obtained for this aspect is 12.36 with the criteria pretty good which the distribution of criteria is presented at Figure 3.

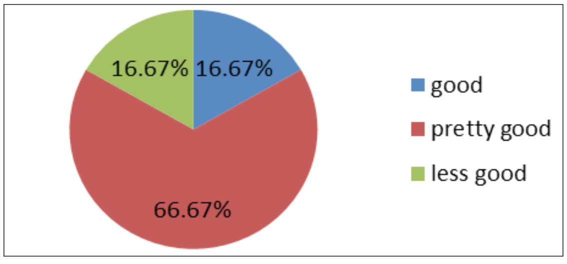

Figure 3. The distribution of criteria for the ability aspect of integrating BC-C with BC-V

The ability of pre-service teacher's to construct the chemistry CoRe in vocational context.

Data for the ability achievement of constructing CoRe derived from an assessment result of the CoRe of Oil for automotive engineering vocational context that it compiled after the learning. The analysis showed that the mean score of CoRe constructing ability obtained was 26.11 and included in the criteria are pretty good. The highest score that can be achieved by the pre-service teachers amounted 34 (75.56% of the ideal maximum score), while the smallest scores only 10 (22.22%). The ability of the majority of pre-service teachers in developing the CoRe documents included in the criteria is sufficient (Figure 5).

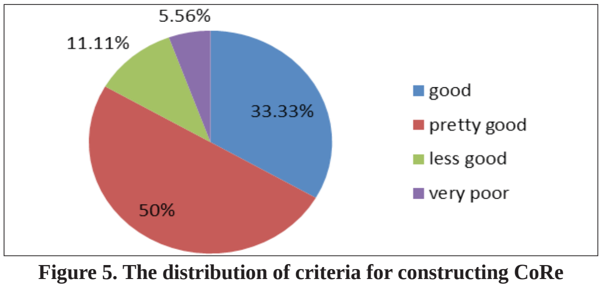

Figure 5. The distribution of criteria for constructing CoRe

The first thing to be done by the pre-service chemistry teachers in developing the CoRe document is to define the main ideas in the petroleum content in accordance with the automotive engineering vocational context. A discussion of this main idea has been done at the previous learning when the pre-service teachers developing matrix chemistry content of vocational context automotive engineering. Results of previous class discussions concluded that there are seven main ideas in the petroleum content emphasized to be taught to vocational school students of Automotive Engineering program.

However, the data in Figure 6 shows that not all the main ideas are raised by pre-service chemistry teachers. Only three main ideas were raised by all of them (36), namely the idea of fractionation of crude oil, gasoline and diesel fuel.

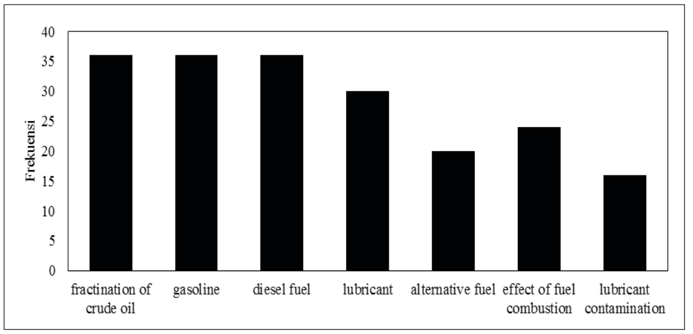

Figure 6. Frequency of emergence of the main idea in the CoRe document

The ability of pre-service teacher'´s to construct the chemistry p-PaP-eRs in vocational context.

The results of an assessment of the p-PaP-eRs documents showed that the average total score obtained is 18,6 and included in the criteria pretty well. The criteria of lowest score of p-PaP-eRs is very poor with a total score of only 9 or 30% of ideal achievement. Meanwhile, the p-Papers with the highest score amounted to 25 with a 83.3% of ideal achievement. The distribution of criteria for constructing p-PaP-eRs is presented at Figure 7.

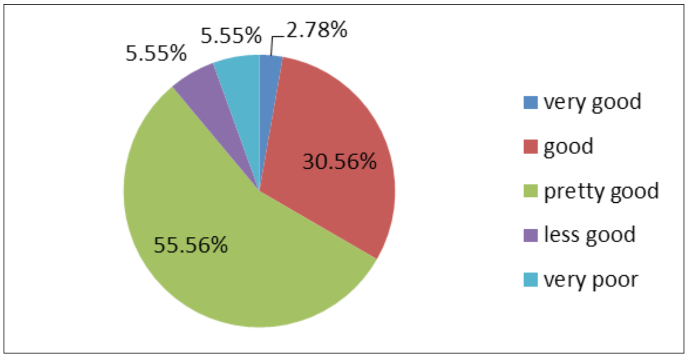

Figure 7. The distribution of criteria of ability for constructing p-PaP-eRs

The ability of pre-service teachers to design learning in the vocational context

Viewed from all aspects, as shown in Figure 8, the average percentage of achievement of the ability to design chemistry learning in vocational context of pre-service chemistry teachers amounted to 64.16%. This achievement included in the criteria pretty well. The ability to analyse the chemistry content of vocational context has the highest level of achievement, in the amount of 72.46% with good criteria. Followed by the ability aspect for constructing p-PaP-eRs with a 62% of level of achievement and last aspect ability of constructing CoRe to the level of achievement of 58.02%. Both aspects are included in the criteria for the achievement of pretty good.

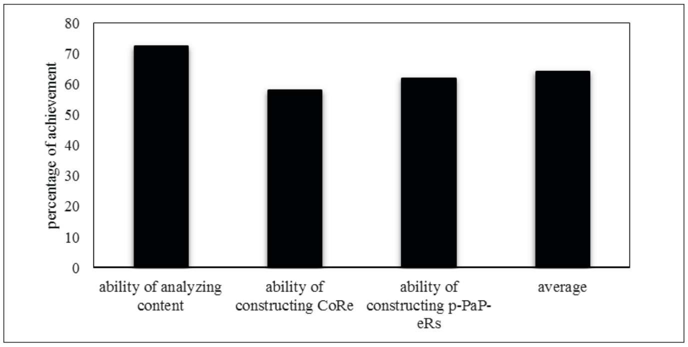

Figure 8. The percentage in achievement of the design learning ability

DISCUSSION

The results of the study showed that the average achievement of ability of pre-service chemistry teachers is pretty good. Judging from the three aspects, only the first aspect i.e. the ability to analyse the chemistry content of vocational context that can be prepared effectively. Ability to analyse the chemistry content of vocational context are relatively better compared to the other aspect because of is supported by prior knowledge of pre-service chemistry teachers. Such knowledge includes basic concepts of curriculum, high school chemistry curriculum as well as how to determine the content that should be studied to achieve certain basic competencies. Knowledge of the curriculum is supporting pre-service teachers' ability to formulate a relationship between topics to build students' prior knowledge and provide the necessary assistance to study topics in the future (Lankford, 2010). Chemistry content analysis capabilities that fit the vocational context require training for pre-service chemistry teachers. Research results of Karisan et.al. (2013) stated that most teachers have limitations in developing PCK in the classroom, especially related how to determine the content that should be taught to meet the overall goal.

While, the second and third aspect of ability in designing learning in vocational context are an ability that requires knowledge and experience that is more complex in order to achieve the optimum result. Constructing of a Core document requires a good basic understanding of the content and pedagogical knowledge. Constructing of p-PaP-eRs requires a comprehensive rationale about a content strategy in teaching as well as experience and reflection on learning. In this study, pre-service teachers had never devised a PaP-eRs before, and have not experienced teaching petroleum content to students, either in general schools or vocational schools.

In the second aspect, there are four indicators with the level of achievement 'less good' and only one indicator reached a good level. The indicator with the lowest mastery is the ability to determine how to make sure the students' understanding. Most of pre-service teachers still rely on pencils and paper tests as a way to ensure student understanding, not yet familiar with the alternative assessment. Meanwhile in the third aspect, there are two indicators with 'less good' level of achievement and just one indicator with level of achievement of good. The indicator with the lowest level of mastery is the ability to anticipate the difficulties that may be encountered in learning. Limited experience teaching practices inhibit pre-service teachers in predicting the difficulties that may be encountered when teaching the content of petroleum, especially for vocational students. This supports previous studies which state that the understanding of the students, including students' perceptions about learning affects the ability of teachers to develop its PCK (Jong & Chuan, 2009).

CONCLUSIONS

After participating in learning, pre-service chemistry teachers have a pretty good ability in designing chemistry learning in vocational context. Pre-service chemistry teachers have a good ability to analyse the chemistry content in vocational context, a pretty good ability in constructing chemistry CoRe in vocational context and a pretty good ability in preparing chemistry p-PaP-eRs in vocational context. The main implication of this research is the need for restructuring of the curriculum for pre-service chemistry teacher education programs that are more concerned with professional development in the context of vocational schools.

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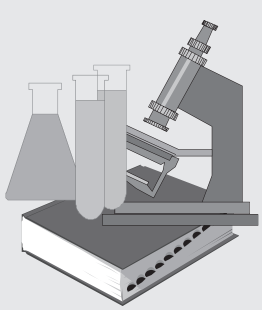
Received 15-10-2016 /Approved 15-05-2017



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Effects of Two Reflective Teaching Strategies on Secondary School Students' Achievement in Biology

Efectos de dos estrategias de enseñanza reflexiva en el rendimiento de los estudiantes de secundaria en biología

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Abstract

The teaching of biology has been beset by routine and poor students' achievement. Most of the instructional methods adopted by teachers failed to improve students' achievement. This is partly because of the inability of biology teachers to carry out reflective teaching in their practices of teaching. Previous studies on biology teaching and learning in Nigeria have concentrated on instructional methods used by teachers as against how teachers actually employ various aspects of the instructional process to impact students' achievement. This study therefore, determined the effects of Reflective Focus Group Discussion (RFGD) and Reflective Peer Observation (RPO) strategies on students' achievement in biology and the moderating effects of teachers' reflective teaching, knowledge and gender.

The study adopted a pretest-posttest, control group, quasi- experimental design. 576 students with eighteen biology teachers were drawn from 9 secondary schools in Ibadan metropolis. The schools were randomly assigned to the two experimental (RFGD and RPO) strategies and the control groups. Instruments used were: Teachers' Instructional Guide for RFGD Strategy, Teachers' Instructional Guide for RPO Strategy, Teachers' Instructional Guide for Traditional Lecture, Instructional Guide for Facilitators, Biology Teachers' Reflective Teaching Knowledge Test, Students' Achievement Test in Ecology. Seven hypotheses were raised and tested at the 0.05 level of significance. Data was analysed using descriptive and inferential statistics.

There were significant differences in students' achievement. Students of teachers in RFGD strategy had the highest achievement mean score=41.8) followed by RPO (12.2) and control (=9.3) groups. Teachers' reflective teaching knowledge and gender had no significant effect on students' achievement. Interaction effect of treatment and teachers' gender was significant on students' achievement ($F_{(2,575)}$=5.4;p0.05;=0.12). The 3-way interaction effect was not significant on students' achievement.

Reflective focus group and reflective peer observation strategies improved students' achievement in biology. Therefore, they should be used by teachers to improve students' achievement.

Key words: *biology, teaching, reflective teaching,*

Resumen

La enseñanza de la biología ha sido criticada por los logros rutinarios y pobres de los estudiantes. La mayoría de los métodos de instrucción adoptados por los maestros no lograron mejorar el rendimiento de los estudiantes. Esto se debe en parte a la incapacidad de los profesores de biología para llevar a cabo la enseñanza reflexiva en sus prácticas de enseñanza. Por lo tanto, este estudio determinó los efectos de las estrategias Reflective Focus Group Discussion (RFGD) y Reflective Peer Observation (RPO) sobre los logros de los estudiantes en biología y los efectos moderadores de la enseñanza, el conocimiento y el género del profesor. El estudio fue organizado en la metodologia de pretest-posttest, grupo de control, diseño cuasi-experimental. 576 estudiantes con 18 profesores de biología fueron entrevistados de 9 escuelas secundarias en la metrópoli de Ibadan.

Hubo diferencias significativas en el rendimiento de los estudiantes. Los estudiantes en la estrategia de la RFGD tuvieron la puntuación media de logro más alta seguido por los grupos RPO y grupo de control . El conocimiento y el género de la enseñanza reflexiva de los maestros no tuvieron un efecto significativo en el logro de los estudiantes. El efecto de la interacción entre el tratamiento y el género de los docentes fue significativo en el rendimiento de los estudiantes. El grupo de reflexión y las estrategias reflexivas de observación por pares mejoraron los logros de los estudiantes en biología. Estos datos pueden ser utilizados por los maestros para mejorar el logro de los estudiantes.

Palabras clave: *biología, enseñanza, enseñanza reflexiva,*

INTRODUCTION

Biology is a science subject which deals with the study of life. The study of the subject among other things provides students with an understanding of the structure and functions of organisms and the relationship of these organisms with their environment. The National Policy on Education (2004;2013) in the objectives of learning secondary school biology stated that the learning of the subject should help provide solutions to most human activities and problems. It is therefore expected that the subject is to be effectively taught by teachers and learned by students in schools.

However, in spite of the importance of biology, students' performance at the secondary school level has not proved to be encouraging. Several researchers such as Odili, (2006) and Ajayi, (2011) have reported the poor performance of students in biology especially in Senior Secondary School Examination.

The poor performance of students may be as a result of their poor understanding of concepts in ecology (Ige, 1998; Tekkaya, Ozkan & Surkur, 2001; WAEC, 2005; 2010;2011) as well as the routine and monotonous teaching of several biology teachers (Ibe and Meduabum, 2001; Udeani & Adeyemo, 2011; Akinfe, Olofinniyi & Fashiku, 2012). Studies have revealed that several biology teachers have been teaching biology concepts in the same manner and have failed to critically consider, analyse and evaluate the nature of teaching activities such as communication, use of instructional materials, inadequate questioning style and poor time management being carried out in the classroom as to how this affects students' performance in the subject. The choice of language, lack of good verbal expression, poor pronunciation of words (Wabuke, 2013) and inadequate or ineffective utilization of instructional materials (Ehikhamenor, 2003) have been observed among most biology teachers. Inadequate questioning style and poor time management (Olaleye, 2011; Potyrala, Walosik & Rzepka, 2011) have been acknowledged to be regular occurrences among biology teachers who thus failed in moving beyond a routine response to classroom teaching.

In order to move beyond routine responses and approach teaching with dynamism, Ferarro (2000), Ajitoni (2008), Onwuachu and Nwaknobi (2009) suggest that teachers should get involved in reflective teaching. Reflective teaching is a deliberate, continuous, systematic, appraisal and assessment of classroom processes. This involves critical analyses of the practice of teaching by teachers in order to consider alternative ways of achieving their ends to bring about better success. Richards & Lockhart (1994), Ajitoni (2008), Menon and Alamelu (2011) described reflective teaching as a practice in teaching whereby teachers collect data about teaching, examine their attitudes and beliefs, assumptions and teaching practices and use the information obtained as basis for critical assessment of their teaching for the purpose of improvement.

When teachers examine their practices of teaching activities for the purpose of improving students' learning, it is hoped that their teaching would not be monotonous in nature. Therefore, in such instances, the nature of students' achievement would also be considered, examined and evaluated and not routinely found to be poor. Farrell (2010) observed that the practice of reflective teaching is made up of certain integral steps such as collection of data which involves gathering of information about classroom events, analysis of data collected, consideration of how the situation or activity could have been different and creation of a new plan that incorporates the findings.

Reflective teaching could be practiced using different strategies. These include: focus group discussion, critical friend, peer observation, diary keeping/journal writing, story sharing or telling, lesson recording, self reporting, mentoring, students' feedback brainstorming, and action research (Hall, 97; Tice, 2004; Taggart & Wilson, 2005; Pollard, 2005; Larrivee & Cooper, 2006; Minott, 2009; Farrell, 2009; Menon & Alamelu, 2011).

According to Taggart & Wilson (2005) Farrell (2007), reflective focus group discussion strategy involves a group of teachers meeting regularly to reflect in order to complement each other's strength and compensate for each other's limitations. The group convenes to systematically consider, analyse and evaluate their teaching beliefs, attitudes, assumptions and practices with a facilitator as the leader of the group to coordinate the activities. Reflective peer observation strategy was described by Tice (2004) and Taggart & Wilson (2005) as involving two teachers taking turns to observe each other in the classroom for reflective activities.

Important as the practice of reflective teaching is to teaching, Ginemeze (1999), Gugapersad (2008) and Minott (2009) report that it has not received due enthusiastic response from teachers. The implication of this is that teachers especially biology teachers do not practice reflective teaching. This may be due to lack of possession of the knowledge and practice of reflective teaching during training or lack of utilization or use of reflective teaching by teacher educators who are mentors to the pre-service teachers. The teacher preparation program had been confirmed to lack the teaching and learning process of reflective teaching due to its non-inclusion in he teacher education curriculum. Therefore, it becomes almost impossible for teachers to have the knowledge of reflective teaching and the ability to engage in its practice. this knowledge gives a confident understanding of a subject with the ability to use it for a specific purpose. If teachers possess the knowledge and practice of the process of reflective teaching, they could have a better understanding of how their management of instruction could impact students' learning and performance.

However, application of knowledge in any practice has been argued by Drudy & Chathan (2002) to be influenced by gender. But Elstad &Turmon (2005) claim that there is no gender difference in teachers' quality of knowledge acquisition and application in the classroom. However, if teachers irrespective of gender possess the knowledge of reflective teaching, there could be better understanding of how this process may have an impact on students' learning and performance.

Several studies have been carried out using most of the strategies of reflective teaching stated above on pre-service teachers. Few studies on in-service teachers have concentrated mostly on language teachers and rarely on physics and science teachers' classroom practices. However, not many reports have been recorded on the extent to which other strategies such as reflective focus group discussion and reflective peer observation strategies influenced students' achievement in a subject like biology.

Therefore, the study focused on the effect of reflective teaching strategies on students' achievement in biology and the moderating effects of teachers' gender and teachers' reflective teaching knowledge.

Hypotheses

Ho$_1$: There is no significant main effect of treatment on students' achievement in Biology.

Ho$_2$: There is no significant main effect of teachers' reflective teaching knowledge on students' achievement in Biology.

Ho$_3$: There is no significant main effect of teachers' gender on students' achievement in Biology.

Ho$_4$: There is no significant interaction effect of treatment and reflective teaching knowledge on students' achievement in Biology.

Ho$_5$: There is no significant interaction effect of treatment and teachers' gender on students' achievement in Biology.

Ho$_6$: There is no significant interaction effect of reflective teaching knowledge and teachers' gender on students' achievement in Biology.

Ho$_7$: There is no significant interaction effect on treatment, reflective teaching knowledge and teacher's gender on students' achievement.

METHODOLOGY

Research Design

A pretest-posttest, control group quasi experimental design was employed.

Population

The population target of this study consisted of all the senior secondary schools in Ibadan metropolis in Oyo State, Nigeria.

Sampling technique and Sample

A random sampling technique was used to select three local government areas from the eleven local government areas in Ibadan metropolis of Oyo State. All the senior secondary schools within the three local government areas were subjected to scrutiny based on the following criteria:

(1) presence of laboratory for teaching Biology

(2) availability of minimum of two qualified teachers teaching Biology in Senior Secondary School II (SS II)

(3) evidence of completion of SS I biology syllabus.

(4) a co-educational school.

In all the 25 schools that met the condition, three schools were randomly selected from each local government area and schools were randomly assigned to two experimental groups (RFGD =174 and RPO = 210 strategies) and control group (n = 192). One intact SS II class was randomly selected per school. In all, a total of 576 biology students made up of male and female students participated in the study.

Instrumentation

The instruments used for the study are:

- Teachers' Instructional Guide for Reflective Focus Group Discussion Strategy (TIGRFD) (Inter-rater reliability index, r = 0.82)
- Teachers' Instructional Guide for Reflective Peer Observation Strategy (TIGRPO) (Inter-rater reliability index, r = 0.80).
- Teachers' Instructional Guide for Traditional Lecture (TIGTL) (Inter-rater reliability index, r = 0.85).
- Instructional Guide for facilitators (IGF) (Inter-rater reliability index, r = 0.72).
- Biology Teachers' Reflective Teaching Knowledge Test (BTRTKT) KR 20 = 0.85.Students' Achievement Test in Ecology (SATB) KR 20 = 0.86.

Procedure for Data Collection

Reflective Focus Group Discussion Strategy, Reflective Peer Observation Strategy and Traditional Lecture Strategy constituted the treatment conditions for the study. The pretest which involves administration of Students Achievement Test in Biology (SATB) to the students and Biology Teachers' Reflective Teaching Knowledge Test (BTRTKT) to the teachers in each group commenced the study and lasted for two weeks. This was followed immediately by the training of teachers for the experimental groups – RFGD strategy and RPO strategy groups. During the training, teachers were introduced to the features of each strategy and given practice sessions. This lasted for two weeks. After this period, the teachers were exposed to the treatment using the instructional guides TIGRFGD, IGF, TIGRPO, TIGTL, for eight weeks, after which the post-test was administered using BTRTKT for the teachers and SATB for the students for two weeks.

Data Analysis

The data obtained was analysed using mean, Analysis of Covariance (ANCOVA), Multiple Classification Analysis (MCA) and Scheffe Post hoc analysis.

RESULTS

The results of the analysis are presented in accordance with the hypotheses raised for the study.

Hypothesis 1: There is no significant main effect of treatment on students' achievement in biology.

Table 1: Summary of ANCOVA of Post-treatment Students' Achievement Scores by Treatment, Teachers' knowledge and Teachers' Gender.

Source of Variance		Hierarchical Method				
		Sum of squares	df	Mean Square	F	Sig
Covariates	PRE	2487.0	1	2487.0	459.7	.00
Main Effects	(Combined)	2378.4	4	594.6	109.9	.00
	TREATMT	2364.2	2	1182.1	218.5	.00*
	TRKNOWL	0.061	1	0.061	.0	.92
	TRGENDER	14.2	1	14.2	2.6	.11
2-Way interactions	(Combined)	76.4	5	15.3	2.8	.02
	TREATMT TRKNOWL	6.1	2	3.1	.6	.57
	TREATMT TR GENDER	58.2	2	29.1	5.4	.01*
	TR KNOWL TR GENDER	16.8	1	16.8	3.1	.08
3-Way Interaction	TREATMT TR KNOWL TR GENDER	32.3	2	16.2	2.9	.05
Model		4974.2	12	414.5	76.6	
Residual		3045.7	563	5.4		.00
Total		8019.9	575	13.9		

*Significant at P .05

Table 2: Multiple Classification Analysis (MCA) of students' Achievement in Biology by Treatment, Teachers' Knowledge and Teachers Gender

Variable + Category	N	Predicted Mean		Deviation		Eta	Beta
		Unadjusted	Adjusted for factors and covariates	Unadjusted	Adjusted for factors and covariates		
Ref Focus Gp Dissc.	174	15.3	14.8	3.3	2.8	.7	.6
Ref Peer Obs	210	12.4	12.2	.4	.2		
Trad Mtd	192	8.6	9.3	-3.4	-2.7		
TR KNOWL Low	360	11.9	12.0	-.09	.03	.0	.0
High	216	12.2	11.9	.2	-.05		
GENDER Male	240	12.0	12.2	.02	.2	.0	.0
Female	336	12.0	11.9	-.01	-.1		
R = .8							

Table 1: shows that there is a significant main effect of treatment on students' achievement in Biology ($F_{(2,575)}$=218.5; p<0.05). This implies that there is a significant difference in the post treatment achievement scores of students exposed to the two strategies (Reflective Focus Group Discussion and Reflective Peer Observation Strategies) than those exposed to the control group. Hence, hypothesis 1 is rejected.

Table 2 is presented to find out the magnitude of the performance of students assigned to the strategies.

From table 2, students exposed to Reflective Focus Group Discussion Strategy obtained the highest adjusted post treatment mean achievement scores (= 14.8; Adj.Dev = .2.8) followed by reflective peer observation strategy (= 12.2; Adj. Dev = .2) and the traditional lecture (= 9.3; Adj. Dev = -2.7) respectively. Thus, reflective focus group discussion strategy was the most effective in improving students' achievement in biology.

Further, the source of the significant difference of treatment on students' achievement was traced using Scheffe Post hoc test.

Table 3: Scheffe Post hoc Tests of Students' Achievement by Treatment

Treatment	N	X	Treatment		
			Focus Gp Diss	Peer Obs	Trad Lect
Focus Gp Dissc	174	14.8		*	*
Peer Obs	210	12.2	*		*
Trad Lec	192	9.3	*	*	

* Pairs of groups significantly different at p .05

Table 3 reveals the significance difference of the strategies. Reflective focus group discussion strategy contributed to the significance difference than others (reflective peer observation and traditional Lecture).

Hypothesis 2: There is no significant main effect of teachers' reflective teaching knowledge on students' achievement in Biology.

From table 1, there is no significant effect of teachers' level of knowledge of reflective teaching on students' achievement in Biology. On this basis, hypothesis 2 is not rejected.

Hypothesis 3: There is no significant main effect of teachers' gender on students' achievement in Biology.

From table 1, teachers' gender has no significant main effect on biology students' achievement ($F_{(1,575)}$=2.6; P>.05). Though, table 2 shows that students taught by a male teacher had slightly higher mean biology achievement score (=12.2) than students taught by their female counterparts (=11.9), it was not significant. Hence hypothesis 3 is not rejected.

Hypothesis 4: There is no significant interaction effect of treatment and reflective teaching knowledge on students' achievement in Biology.

Table 1 shows that there is no significant interaction effect of treatment and teachers' knowledge on students' achievement in Biology ($F_{(2,575)}$ = 6; p>.05). On this basis hypothesis 4 is not rejected.

Hypothesis 5: There is no significant interaction effect of treatment and teachers' gender on students' achievement in Biology.

From table 1, there is a significant interaction effect of treatment and teachers' gender on students' achievement in Biology ($F_{(2,575)} = 5.4; p<.05$). Hypothesis 5 is therefore rejected.

Hypothesis 6: There is no significant interaction effect of teachers' reflective teaching knowledge and teachers' gender on students' achievement in Biology.

Table 1 shows that there is no significant interaction effect of teachers' reflective teaching knowledge and teachers' gender on students' achievement in Biology ($F(2,575)=3.1; P>.05$). Hypothesis 6 is therefore not rejected.

Hypothesis 7: There is no significant interaction effect of treatment, teachers' reflective teaching knowledge and teachers' gender on students' achievement in Biology,

From table 1, there is no significant 3-way interaction effect of treatment, teachers' reflective teaching knowledge and teachers' gender on students' achievement in Biology ($F_{(2,575)} = 2.9; p>.05$). Hypothesis 7 is therefore, not rejected.

DISCUSSIONS

The two strategies of reflective teaching (Reflective Focus group discussion, and reflective peer observation) used in this study proved to be efficacious in improving students' achievement in Biology. The results in tables 1, 2 and 3 showed significant difference between scores of students exposed to the strategies of reflective teaching and traditional lecture (control group). Since the mean scores obtained by students in the treatment groups i.e RFGD strategy with achievement mean score (14.8) followed by RPO (12.2) were higher than the control group mean scores (9.3) then the efficacy of the two strategies were revealed.

The increase in the mean scores of the achievement of students in the treatment groups might be due to the exposure of their teachers to reflective practices such as critical consideration, examination and evaluation on teaching activities which consequently led to better students' performance. This corroborates Lowery's (2003) assertion that reflective teaching practice has the potential to affect students' achievement in mathematics and science classrooms. The reflective activities of biology teachers must have enhanced and enriched their teaching and this consequently, opened the door to more efficient learning of their students and increased their achievement. This is also in agreement with Akbari and Allvar's, (2010) submission that there is a high correlation between teachers' reflectivity and students' achievement. The reason according to the study is that reflective practice is first centered on students' learning.

Students of teachers in the reflective focus group discussion strategy had a higher mean score than students of teachers in the reflective peer observation strategy. The advantage of students of RFGD strategy over students of RPO strategy teachers might be due to the number of teachers who were involved in carrying out reflective activities in the RFGD strategy. The more number of teachers in RFGD strategy must have generated various ideas during reflection activities due to their number in the group which made the teachers to become more effective in improving students' learning and consequently students' achievement. This is in agreement with Roig and Rivera (2013) who submitted that group reflection helps teachers to learn and modify their students' learning.

The improvement of students of biology teachers which might have occurred due to peer reflection of the teachers compared to traditional lecture where an individual biology teacher was responsible for planning of classroom teaching with no reflection, hence such individual teachers are less effective. This is in support of Marzano and Toth (2012) who remarked that even small improvements in teachers' effectiveness can have a possible impact on students' achievement. The little reflective activities by two teachers in RPO strategy must have produced positive influence on students' achievement as compared to the traditional group with only one teacher without systematic reflection.

However, the result obtained indicated a significant interaction effect of treatment and teachers' gender on students' achievement. The interaction effect showed that in RPO strategy students of male teachers performed slightly higher in achievement scores than students of female teachers. This may be due to possession of other characteristics like good problem solving abilities by the male teachers. Possession of such characteristics might have boosted the effect of reflective teaching on the students' learning due to the ability of the males to modify the teaching style thus enhancing students' achievement. Corroborating this assertion, Udeani and Adeyemo (2011) reported that a biology teacher with good problem solving abilities will be able to modify the teaching style to suit the students' learning thus, enhancing their academic achievement. However, the finding from this study is contrary to that of Akbari and Allvar (2010) and Nevaneedhan (2011) who found that the practice of reflective teaching produces better academic performance of students irrespective of teachers' gender.

CONCLUSIONS

This study showed that reflective teaching had proved to be important in improving students' achievement. However, the study has also revealed that reflective teaching by focus group discussion strategy improved students' achievement more than the reflective peer observation strategy does. This implies that with practice of reflective teaching by biology teachers, especially with the strategies such as reflective focus group discussion and reflective peer observation, students' achievement in biology would be improved. It is believed that the practice of reflective teaching in classroom teaching in biology would greatly improve students' learning and consequently students' achievements.

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Received 20-11-2016 /Approved 15-05-2017

Las pizarras digitales interactivas en la enseñanza de ciencias: visión del profesorado de educación secundaria y bachillerato

Interactive whiteboards in the teaching of science: vision of secondary education teachers

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Resumen

En este artículo se explora cómo los profesores de secundaria y bachillerato utilizan las tecnologías y en concreto las pizarras digitales interactivas (PDI) en la enseñanza de ciencias, así como las percepciones que tienen de su uso. Se utilizó un enfoque metodológico cualitativo, realizándose entrevistas semiestructuradas a un total de veintisiete profesores de educación secundaria y bachillerato de Andalucía (España). La codificación y reducción de datos se realizó con el software Atlas.ti, dando lugar a once categorías que facilitaron el análisis. Entre los resultados obtuvimos que los profesores de ciencias utilizan las tecnologías, y en especial la PDI como herramientas habituales en sus clases, que les permite explicar los conocimientos científicos y les facilita a los estudiantes la comprensión de los mismos; perciben la precariedad de recursos tecnológicos y los problemas técnicos como obstáculos para su implantación. Y que los constantes avances tecnológicos hacen necesaria una formación continua del profesorado, con el fin de poder utilizar el potencial pedagógico que ofrece la PDI y las tecnologías que están surgiendo.

Palabras clave: *pizarra digital interactiva; nuevas tecnologías; educación secundaria; percepción docente; enseñanza de ciencias.*

Abstract

This article explores how teachers of junior high and high school use technologies and specifically interactive whiteboards (IWB) in science education, as well as perceptions of their use. A qualitative methodological approach was used, semi-structured interviews were done with a total of twenty-seven teachers sciences in junior high schools and high schools in Andalusia (Spain). Coding and data reduction was performed with the software Atlas.ti, resulting in eleven categories that facilitated the analysis. Among the results we obtained were that science teachers use technologies, and especially the PDI as usual tools in their classes, allowing them to explain scientific knowledge and provide students with an understanding thereof.Science teachers perceive the precariousness of technological resources and technical problems as obstacles to its implementation. Also, constant technological advance makes necessary a continuous training of teachers in order to fully use the educational potential of the PDI and emerging technologies.

Keywords*: interactive whiteboard; new technologies; secondary education; teacher perception; science education.*

INTRODUCCIÓN

La utilización de pizarras digitales interactivas (PDI) en los centros de educación secundaria y bachillerato españoles es un fenómeno relativamente nuevo que en los últimos años ha ido en aumento, llegándose a convertir en una herramienta eficaz en el proceso de enseñanza y aprendizaje. La Comisión Europea (2013) puso de manifiesto que los centros europeos disponen de una PDI por cada 100 estudiantes en todos los niveles educativos, encontrándose España entre las diez primeras. Según datos del Ministerio de Educación, Cultura y Deporte (2015) los centros de secundaria y bachillerato españoles disponen de una PDI por cada 50 alumnos, muy por encima de la media Europea. Al ser la radio de estudiantes por aula 24, aunque el 100% de los centros disponen de PDI solo el 20% de las aulas lo pueden utilizar diariamente, siendo 1º y 2º de secundaria donde mas se utiliza.

El surgimiento y mayor crecimiento de la PDI tuvo lugar en el Reino Unido, donde la inversión pública llevó a un aumento exponencial de las mismas en los centros educativos ingleses (Mercer, Warwick, Kershner y Staarman, 2010). A nivel mundial cada vez es mayor la importancia que la utilización de la PDI está adquiriendo en los contextos educativos, y son más numerosos los proyectos y estudios llevados a cabo acerca de su puesta en funcionamiento en clase. Desde que se empezó a utilizar en las aulas, la mayoría de los estudios se han centrado en aspectos como: las percepciones y actitudes de los profesores hacia el uso de PDI en las aulas (Isman, Abanmy, Hussein y Al Saadany, 2012; Oz, 2014), el uso de la PDI en el proceso de la enseñanza y el aprendizaje (Emron y Dhindsa, 2010) y el efecto de motivación e interacción de la PDI (Sarsa y Solar, 2011).

Los beneficios que el uso de la PDI ofrece a los estudiantes, los profesores y las posibilidades de aprendizaje, han supuesto un aumento de su utilización en diversos entornos de aprendizaje y disciplinas. La ciencia es una de las disciplinas donde su uso en la enseñanza es cada vez mayor. Los programas de software interactivos de la PDI ayudan a centrar la atención de los estudiantes en el contenido que se explica en clase, les permiten visualizar los procesos científicos, hacer sus errores más fácilmente identificables y promover el intercambio de conocimientos mediante el diálogo. El uso de la PDI en aulas de educación secundaria proporciona mayor número de recursos, y potencian materias como las Ciencias Naturales, la Física y Química, ya que la percepción visual y la interactividad ayudan a la comprensión de conceptos. La PDI también permite un rápido acceso a Internet, proporcionando a profesores y estudiantes la posibilidad de utilizar una amplia variedad de contenidos web educativos, cargados de videos, fotografías y materiales de texto que enriquecen sustancialmente el entorno de enseñanza en las clases de ciencia (Coyle, Yañez y Verdul. 2010). Para Skutil y Maněnová (2012) la principal razón para usar la PDI en la enseñanza de las ciencias es la visualización, pues ofrece mayor posibilidad de usar una amplia serie de materiales que en su mayoría son imágenes. Por otra parte, la PDI se puede utilizar para registrar mediante grabaciones con su software específico las modificaciones en los contenidos usados en el aula, que al ser guardadas los profesores pueden volver a reproducir, permitiéndoles comprobar tanto los avances como los errores que se comenten en el proceso de enseñanza-aprendizaje en clase. Desde el punto de vista de Murcia y Sheffield (2010) el uso eficaz de la PDI por los profesores puede motivar y llamar la atención de los estudiantes a través de una amplia gama de recursos digitales que les permite explorar la importancia de la ciencia en el mundo que nos rodea y construir conocimientos de los conceptos científicos clave.

Ormanci, Cepni, Deveci y Aydin (2015) manifiestan que es evidente la necesidad de llevar a cabo más investigación sobre el uso de la PDI en la educación científica, sobre todo el efecto de esta tecnología en las destrezas de los estudiantes, pues la mayoría de los estudios realizados se han centrado en los efectos de la PDI en el rendimiento académico y los resultados de aprendizaje de los estudiantes. Pero las principales cuestiones que en los últimos años se están investigando son: la contribución de la PDI en el proceso de educación, su uso en los entornos y los problemas que se producen cuando se utiliza en clase.

En el campo de la ciencia nos encontramos con estudios que han asociado el uso de la PDI con un incremento de la motivación de los estudiantes (Cassapu, 2009), el compromiso y rendimientos académicos, pero la mayoría de ellos ignoran el papel del profesor en la ejecución de esos cambios positivos. En esta línea Stroud, Drayton, Hobbs y Falk (2014) observaron la práctica de 28 profesores de ciencias en centros de secundaria, los cuales integraban la PDI en sus actividades de clase. Encontraron tres patrones de uso de esta tecnología en clase de ciencia: los primeros en usar la PDI, los usuarios típicos y los que se resisten a su uso. Siendo la principal barrera para la integración una falta de conocimiento sobre las características y funciones de la PDI.

Para Akbas y Pektas (2011), aunque se ha demostrado que las prácticas de laboratorio de ciencias naturales facilita el aprendizaje de los estudiantes a través de técnicas de observación y experimentación, no es el método de enseñanza preferido en los centros educativos debido a la falta de equipos de experimentación o a la preocupación de no disponer de tiempo suficiente para cubrir todo el plan de estudios a través de experimentos. Lo cierto es que las tecnologías como la PDI pueden llegar a ser herramientas ideales para aumentar el interés y la curiosidad de los estudiantes hacia los temas científicos. La PDI permite desarrollar simulaciones y experimentos virtuales que requieren la participación del alumno, bien utilizando los propios materiales desarrollados con los software de la PDI, o bien los disponibles en internet. Wieman, Adams, Loeblein y Perkins (2010) utilizando la PDI en clase de física y química realizaron simulaciones virtuales para enseñar el electromagnetismo, mostrando el motor eléctrico, la campana eléctrica y la generación de la corriente de inducción.

Para Jang y Tsai (2012) las razones que llevan al profesorado a utilizar o no la PDI en clases de ciencias son: logran más fácilmente la atención de los estudiantes, les ayuda a concentrarse en el aprendizaje, a explicar conceptos complejos y abstractos; a que el proceso de enseñanza sea más suave y mejore la eficacia de la enseñanza, no producen polvo de tiza, aumenta la interacción entre profesores y estudiantes, y les ayuda a ser más flexibles en el uso de diferentes materiales. Siendo las limitaciones presupuestarias y la falta de tiempo para diseñar materiales didácticos las razones más importantes por las que los profesores no utilizan la PDI en clases de ciencias. En un estudio anterior, Jang (2010) manifestó que los profesores de ciencias utilizan la PDI como herramientas de enseñanza para compartir sus conocimientos de la materia y para conseguir la comprensión de los estudiantes. Además, esta tecnología ayudaba a los profesores que encontraban dificultades en el aula para aplicar mejor sus repertorios de representación y estrategias de instrucción. El uso de la PDI en clases de ciencias permite una mayor flexibilidad de instrucción y acceso a la información (Gadbois y Haverstock, 2012), y puede ser utilizada de diferentes maneras: como herramienta de presentación y como medio para que los estudiantes desarrollen sus propios conocimientos.

Propósito de la investigación

El problema de investigación planteado en este estudio fue explorar las formas en que los profesores de centros de secundaria y bachillerato españoles utilizan las tecnologías y en concreto la PDI en la enseñanza de materias relacionadas con las ciencias, en asignaturas de biología, química, física y geología, así como las opiniones que tienen sobre el uso de la PDI. Por ello como objetivos de investigación planteados fueron conocer los siguientes aspectos:

- Las tecnologías que los profesores utilizan en la enseñanza de las disciplinas de ciencias en educación secundaria y bachillerato. En especial, si la PDI es utilizada como tecnología habitual en dicho proceso de enseñanza y aprendizaje.
- Qué tipo de capacitación digital poseen los profesores para integrar los medios tecnológicos, y en concreto la PDI en la enseñanza de asignaturas de ciencias.
- Los obstáculos que encuentran los profesores para integrar el uso de tecnologías como la PDI en las clases de ciencias.
- Qué factores piensan los profesores que puede mejorar la integración de la PDI como herramienta de enseñanza.
- Los beneficios que el uso de la PDI ofrece en las clases de ciencias en secundaria y bachillerato.

METODOLOGÍA

Para este estudio se eligió un diseño de investigación cualitativa que abarca distintas fases en las que no existe un inicio y un fin claramente definido (Hernández, 2014). A lo largo del proceso estas fases se entremezclan dando lugar a una espiral-reflexiva continua (Denzin y Lincoln, 2012). En concreto utilizamos un tipo de investigación cualitativa a la que Flick (2012) denomina interaccionismo simbólico, en las que el punto de partida se centra en “las diferentes maneras en que los individuos revisten de significados los objetos, los acontecimientos, las experiencias, etc...” (Hernández, 2014, p. 189).

Muestra

Se utilizó una estrategia de muestreo intencional (Patton, 2002) como forma de recolección de datos de sujetos en la investigación. Los participantes en este estudio fueron 27 docentes, de los que el 59,3% (f=16) eran mujeres y el 40,7% (f=11) hombres. Con una edad media de 43 años y una experiencia docente media de 20 años. Eran licenciados en diferentes estudios científicos: biología (f=16), química (f=6) y física (f=5). Todos los docentes durante la realización de este estudio impartían docencia en asignaturas de las que eran especialistas, Biología y Geología, Ciencias del Mundo Contemporáneo y Biología, Ciencias Naturales, Métodos de la ciencia, Química, Física, y Física y Química, en 27 Institutos de Educación Secundaria y Bachillerato de Andalucía (España).

Recolección de datos

La herramienta de recogida de datos utilizado fue la entrevista, desde la que se asume que lo que alguien tiene que decir es "significativo, cognoscible, y capaz de hacerse explícito" (Patton, 2002, p. 341). Con el uso de la entrevista cualitativa tratamos de entender el mundo desde el punto de vista del sujeto (Hernández, 2014). Se utilizó un estilo de entrevista semiestructurada, para obtener información sobre la disposición y uso de las TIC en las clases de ciencias, así como la experiencia docente del uso de las TIC en el proceso de enseñanza.

Análisis de datos

Para el análisis e interpretación de los datos se realizó el análisis del contenido de toda la información recogida de las entrevistas realizadas a los profesores. Tras la grabación de las veintisiete entrevistas en audio, se procedió a la transcripción de las mismas en formato de texto. A continuación se llevó a cabo una primera lectura de toda la información recogida en las entrevistas, para tener una visión de conjunto del tema estudiado. A partir de aquí se identificaron los códigos, y categorías a las que hace referencia cada código. La codificación y reducción de datos se realizó con el programa informático Atlas.ti, versión 6.0, obteniéndose once categorías, que son: formación docente en TIC; apoyo de la administración; implantación de las TICs y PDI; influencia del uso de TICs y PDI; posibilidades de las TICs y la PDI; frecuencia de uso; uso de TICs y PDI; percepción docente; selección, diseño y creación de materiales; beneficios y obstáculos.

RESULTADOS

A partir de la interpretación analítica de las entrevistas realizadas se describen e interpretan los hallazgos obtenidos en el estudio.

Categoría: Formación docente en tecnología. Las entrevistas realizadas a los profesores ponen de manifiesto la importancia de tener una formación adecuada sobre los nuevos recursos tecnológicos. Siendo relevante que todos los entrevistados afirman que la formación que poseen sobre el uso de tecnologías como la PDI fue obtenida de cursos recibidos de la administración educativa y de forma autodidacta. "Al principio, como he dicho antes, autodidacta, y luego pues he ido especializándome con las distintas ofertas educativas que ofrece la administración, hacia los profesores y los centros de estudio del profesorado" (Entrevista 16, 14/6/2015). Aun así los entrevistados están de acuerdo con la idea que necesitan tener una formación continua en temas de tecnología, pues los avances son tan rápidos que quedan obsoletos a corto plazo. "Siempre, la formación tiene que ser constante, ya que, la evolución de las tecnologías lo es" (Entrevista 8, 1/5/2015).

También manifiestan carecer del tiempo libre necesario para mejorar su formación en temas tecnológicos, "y me queda mucho por aprender, lo que pasa que eso lo que estamos diciendo sería hacerlo aparte de mi trabajo y ahora mismo tengo el tiempo limitado" (Entrevista 11, 12/5/2015). Poseer formación les aporta seguridad para utilizar la tecnología de forma más correcta y adecuada. "Para que los profesores más veteranos le pierdan el miedo, los que lo tengan, y los jóvenes, que no vienen tan preparados como parecen" (Entrevista 8, 1/5/2015).

Categoría: Apoyo de la administración. Esta categoría hace referencia al apoyo que los entrevistados perciben por parte de la administración respecto al uso de las TICs en clase. Todos los docentes manifiestan que hace unos años existió un auge de las TICs que se vio reflejada en la instalación en los centros educativos, pero que como consecuencia de la crisis que está sufriendo el país en estos últimos años dicho auge ha quedado estancado. "En los momentos que estamos corriendo de crisis la administración no potencia el uso de tecnologías, ya que los centros no disponen de recursos económicos para ello" (Entrevista 1, 1/5/2015).

Categoría: Implantación de las TICs. Los docentes perciben una serie de obstáculos para la implantación de las TICs en las aulas de ciencias, pues aunque las administraciones facilitan su inserción en clase, los sistemas informáticos y la infraestructura de los centros en la mayoría de los casos son precarios para poder hacer un uso diario y adecuado de las tecnologías. Los principales conflictos que manifiestan están vinculados con las instalaciones eléctricas y conectividad de la red. "El principal problema es la utilización de Internet vía Wifi, puesto que a veces la señal es insuficiente o nula y se te va la señal a mitad de la clase, esto hace que impartir las clases con normalidad sea bastante duro" (Entrevista 2, 4/5/2015).

Categoría: Influencia del uso de TICs y PDI. En relación a la influencia que los profesores piensan que tiene el uso de la tecnología en el aprendizaje de asignaturas de ciencias por los alumnos, todos perciben que ejercen un efecto positivo y motivador, aumenta la atención de los estudiantes en clase, hace más atractivo el aprender a través de vídeos y/o documentales, evitando la monotonía tradicional de las explicaciones del docente. "Pienso que la tecnología nos ofrece un aprendizaje mucho más significativo porque favorece la dinámica en la clase, el alumno está mucho más activo y favorece la interrelación alumno-profesor haciéndome preguntas y adquieren mucho mejor el conocimiento." (Entrevista 4, 5/5/2015)

Perciben que el uso de las PDI aumenta el interés y la comprensión de los contenidos que se enseñan, así como la motivación de los estudiantes, al hacer las clases más divertidas. "Ejerce un efecto positivo porque ellos están acostumbrados a usar las tecnologías en muchos ámbitos de su vida y el usarlo en la educación también hace que esta sea más cercana y divertida para ellos" (Entrevista 7, 7/5/2015).

Los profesores ven que la utilización de imágenes con la PDI en clases de ciencias facilita el aprendizaje, pues al visualizar lo que explica el docente hace que los estudiantes entiendan mucho más rápido y de manera impactante las explicaciones científicas. "Yo creo que permite comprender cuestiones que son difícilmente asumibles mediante la animación, la imagen, lo audiovisual, en general lo multimedia, permite acceder a esos contenidos de forma mucho más sencilla y más asumible por el alumnado" (Entrevista 16, 15/6/2015).

El uso de la PDI también influye en la metodología docente, ya que la dinámica de clase es diferente, "por un lado lo hace más visual, más intuitivo, se ven mejor las cosas se entienden mejor y deberían influir de otra manera también, y es que cambiaría la manera en que los profesores damos clase no solamente que el profesor es el que llega y te cuenta las cosas que pasan sino que el alumno aprendiera a utilizar la tecnología pudiendo acceder él a la información y elegir la información que le interesa para las tareas que tú le estés proponiendo, este segundo paso todavía no debería llegar pero a día de hoy aquí no estamos al menos ahí" (Entrevista 9, 8/5/2015).

Les permite explicar de manera más clara y concisa a los estudiantes, por lo que el aprendizaje es más rápido. "Te permite variar la metodología bastante y hace que las explicaciones sean bastante más dinámicas y atractivas para los alumnos. Si además tienes una buena conexión a internet, accedes a una gran cantidad de recursos de manera inmediata, lo que irá en pro de dichas explicaciones" (Entrevista 2, 4/5/2015).

Categoría: Posibilidades de las TICs y la PDI. Los entrevistados perciben que son muchas las posibilidades que las TIC y la PDI ofrecen a la enseñanza de ciencias. Destacan que facilita su labor docente, "te permite disponer de una enorme cantidad de recursos en un instante, cosa que anteriormente te llevaba una serie de horas el prepararlas" (Entrevista 2, 4/5/2015).

Perciben la tecnología como el futuro de la educación, siendo cada vez mayor las posibilidades que van a ofrecer, "Infinitas posibilidades ya que tiene toda la información que ofrece internet y al mismo tiempo permite al alumno resumir, sintetizar, seleccionar, buscar toda esta información" (Entrevista 14, 14/5/2015).

Otra de las posibilidades que resaltan los profesores es que el uso de tecnología y en especial la PDI hacen las clases más atractivas e interesantes facilitando el proceso de aprendizaje de los alumnos, "ayuda a la comprensión de los diferentes conceptos y de los procesos que se explica en biología y geología, los recursos que más me gustan para mi asignatura son las animaciones y los videos didácticos, también me gusta por la rapidez a la hora de buscar información" (Entrevista 27, 29/5/2015).

Categoría: Frecuencia de uso. La mayoría de los profesores manifiestan que utilizan a diario la PDI en la enseñanza de ciencias, ya que las aplicaciones y actividades interactivas que ofrecen hoy día la red son innumerables. La utilizan sobre todo para proyectar vídeos e imágenes pues aumenta la atención y la participación del estudiante, al tiempo que permite que comprendan mejor lo que se les explica. "…todo lo utilizo como apoyo para explicar, sobre todo hay imágenes en movimiento que parece evidente poderlas utilizar, o para determinadas situaciones, en orgánica por ejemplo es muy útil no tener que escribir estructuras orgánicas y no perder tiempo" (Entrevista 17, 15/5/2015).

Categoría: Uso de las TICs y PDI. Los profesores entrevistados ponen de manifiesto que con la utilización de las TIC y en concreto la PDI en la enseñanza de ciencias se saca un gran partido, ya que el simple hecho de poder mostrar imágenes relacionadas con los temas de clase hace que se entiendan mejor lo que enseñan. Los usan para mostrar videos y realizar actividades interactivas. Opinan que las TIC ayudan en la comprensión de conceptos y procesos científicos que se explican en materias como biología, física y/o química. "Ayuda al aprendizaje ya que el alumnado visualiza y tiene un acceso más instantáneo y general de los contenidos" (Entrevista 10, 11/5/2015). Afirman que la PDI les capacita para llegar de una forma más atractiva y cómoda al estudiante al enseñar temas de ciencias, además de ahorrarles tiempo en las explicaciones de clase, ya que al usar imágenes y/o vídeos les evita tener que dedicar tiempo a dibujar lo que se explica. "…no es lo mismo dibujar en la pizarra, que utilizar un programa de geometría interactiva que te permite hacer un diseño y ahora ir viendo cómo van variando los resultados de una construcción geométrica, variando los distintos elementos, eso no se puede hacer en una pizarra clásica" (Entrevista 16, 15/6/2015).

Casi la totalidad de los docentes que han participado en la investigación, el 90% utilizan la PDI a diario, y de muy diferentes maneras: para realizar actividades interactivas, poner vídeos, explicar contenidos, hacer esquemas, etc… Así lo ponen de manifiesto: "se usaba para todo eso: realización y corrección de ejercicios, dibujos, gráficos, comentarios de imágenes, apoyo a exposiciones orales, corrección de trabajos escritos, visualización de los portafolios digitales de los alumnos" (Entrevista 14, 14/5/2015).

Categoría: Percepción docente. Esta categoría resalta cómo los profesores *perciben el uso de la PDI* en clases de ciencias. Nos encontramos con profesores que la ven necesaria en su práctica diaria, pues como hemos comentado les facilita el trabajo y hace las clases de ciencias más cómodas, prácticas y amenas a los estudiantes. La perciben como una gran ayuda a aprender y enseñar, "son recursos que facilitan el aprendizaje" (Entrevista 4, 5/5/2015).

Categoría: Selección, diseño y creación de materiales. Algo que nos interesó era saber qué estrategias seguían los profesores para seleccionar, diseñar y/o crear los materiales didácticos que utilizan con los ordenadores y la PDI. Los profesores entrevistados informan que los materiales que suelen crear son para usarlos con el PowerPoint y proyectarlos sobre la PDI. "Las clases de Biología y Química de segundo de bachillerato las doy a partir de mis presentaciones Power Point para que ellos lo comprendan mejor. Es un material que me ha costado años crear y que cada año voy perfeccionando" (Entrevista 3, 5/5/2015).

Nos encontramos con que solo cinco de los profesores adaptan a sus clases el material que sobre temas de ciencias se encuentran disponibles en la red, pues le resulta más cómodo y les ahorra tiempo. "…busco material que ya está trabajado y lo adapto yo a mí. A la hora de hacer presentaciones o documentales, voy cogiendo lo que necesito y adaptándolo a lo que yo necesito en ese momento" (Entrevista 12, 12/5/2015).

Diez de los profesores entrevistados reconocen que en la red existe un amplio número de recursos educativos abiertos que pueden ser utilizados directamente en las distintas asignaturas de ciencias" Si, existen muchos blogs de compañeros que te facilitan el trabajo, y si sabes buscar, encuentras muchos materiales muy interesantes y útiles. Yo también cuelgo en la página web del centro algunas cosas que se hacen en el centro y no solo yo, también mis alumnos". Así por ejemplo afirman que "hoy día hay un amplio abanico de recursos, hay muchos bancos de recursos, incluso elaborados por los propios proveedores de la pizarra, que te permiten en un par de clics localizar lo que tú necesitas sin tenerlo que elaborar, entonces es mucho más inmediato" (Entrevista 16, 15/6/2015).

Los criterios que los profesores manifiestan que utilizan para seleccionar el material que hay en la red, son: buscar materiales atractivos que motiven a los estudiantes, que "se adapten al nivel de comprensión" (Entrevista 5, 6/5/2015), "que tengan rigor científico y sean atractivos para el alumnado" (Entrevista 6, 7/5/2015), "que cumplan los objetivos del currículo, que sean claros, concisos, motivadores y que me permitan evaluar las competencias básicas de los alumnos" (Entrevista 14, 14/5/2015), "que se adapten al contenido, al nivel, a los intereses del alumnado con el que estoy trabajando en ese momento" (Entrevista 16, 15/6/2015).

Categoría: Beneficios. Los *beneficios* que los profesores perciben del uso de las TIC y en concreto de la PDI en las clases de ciencias son diversos. Por un lado, aumenta la motivación de los estudiantes, haciendo que se muestren más participativos en clase. Hace más atractivo a los estudiantes el contenido de las materias de ciencias. La PDI da la opción "de acceder a los contenidos por parte del alumnado, son medios atractivos que facilitan la comprensión" (Entrevista 6, 7/5/2015). "El uso de pizarras digitales es más atractivo para los alumnos que el libro de texto" (Entrevista 2, 4/5/2015). Capta muy fácilmente la atención de los estudiantes. "Sí atrae más la atención, están dispuestos a participar más, tú le dices a un niño que salga a hacer una actividad con la tiza seguramente te dice que no, seguro que si se lo dices en la pizarra digital, le llama más la atención y está más dispuesto a salir por el hecho de utilizar la pizarra digital" (Entrevista 17, 15/5/2015).

Los docentes afirman que las TIC permiten la búsqueda de información de manera rápida e inmediata, "produce un efecto muy positivo ya que se amplía información rápidamente sobre la marcha, se pueden ver ejemplos, fotos, gráficos, películas relacionadas con los temas que se estudian" (Entrevista 19, 18/5/2015). También les da la opción de poder reunir de forma conjunta imágenes y sonidos, dotando de interactividad el proceso de enseñanza y aprendizaje en las clases de ciencias. Los docentes afirman que con la PDI "no sólo captamos información textual sino que estamos constantemente con información gráfica, información de imagen en movimiento, información auditiva. En la pizarra clásica, eso no se puede, tú puedes dibujar trazos pero pierdes dinamismo, pierdes medios. Con una pizarra digital, tú adaptas la capacidad multimedia de captar información a la forma de ofrecer esa información al alumnado" (Entrevista 16, 15/6/2015).

Por otro lado, el uso de la PDI evita la aparición de muchas enfermedades de piel, causadas por la tiza de las pizarras tradicionales. "La pizarra digital es mucho más limpia comparada con la pizarra tradicional y con la tiza, la cual, en ocasiones crea problemas de piel, de grietas, de enfermedades relacionadas con la piel. Y para los que la padecemos, la pizarra digital viene a solucionar todo eso" (Entrevista 2, 4/5/2015).

Categoría: Obstáculos. La gran mayoría de los entrevistados afirman que la PDI no presenta obstáculos para su utilización en clase de ciencias, sino que los ponen ellos mismos en la mayoría de las situaciones. "La pizarra digital es una ayuda más y no limita el proceso para nada" (Entrevista 8, 1/5/2015). Algunos profesores manifiestan que los obstáculos que surgen suelen ser por problemas técnicos por falta de mantenimiento y/o fallas en las conexiones de internet. La mayoría no posee formación técnica para solucionar problemas surgidos lo que les limita para su uso adecuado, "la única limitación está en los medios técnicos, si la pizarra funciona todo va estupendamente, y si tu todo lo has pasado a la pizarra digital y la pizarra falla pues entonces no puedes, ahí te estás frenando, tienes que volver a los recursos clásicos" (Entrevista 16, 15/6/2015)

DISCUSIÓN

Los resultados del estudio indican que las PDIs poseen el potencial de influir positivamente en la enseñanza y el aprendizaje de asignaturas de ciencias, desde el momento que permite a los profesores crear fácil y eficientemente presentaciones y actividades multimedia flexibles e interactivas, obtenerlas de la red o de las propias páginas de los fabricantes de las PDI. La interactividad y el atractivo que presentan el entorno multimedia permite aumentar la participación y la motivación de los estudiantes, captar el interés y la atención de éstos, y mejorar el aprendizaje. Son utilizadas por los profesores como tecnología habitual en las clases de ciencias, que no solo hace las clases de ciencias más atractivas e impactantes, sino que también permite una comprensión más fácil por parte de los estudiantes de las explicaciones y los conceptos científicos.

Las opiniones del profesorado presentado anteriormente, dejan claro que la PDI posee un gran potencial para facilitar la instrucción debido a las numerosas ventajas que tiene: fácil uso, interactividad, adaptabilidad a diferentes entornos, y posibilidad de uso con diferentes métodos y técnicas de enseñanza.

Este estudio también ha revelado que los profesores que enseñan ciencia necesitan un mayor desarrollo profesional para mejorar sus habilidades y la capacidad para el uso efectivo de la PDI, perciben la falta de formación en TIC´s como un obstáculo. Algunos estudios enfatizan la importancia de los programas de desarrollo profesional docente para la integración efectiva de las tecnologías y la PDI (Isman, Abanmy, Hussein, y Al Saadany, 2012). Los trabajos de Becta (2004) y Pamuk, Cakir, Ergun, Yilmaz y Ayas (2013) también señalaron la necesidad de formación docente permanente con el fin de tener una implementación exitosa, no sólo de la PDI, sino de todas las herramientas tecnológicas.

Pero la formación no debe ser sólo de carácter técnico, en términos de cómo utilizar la tecnología, sino también debe incluir la formación pedagógica para ayudar a los docentes a integrarla correctamente en la dinámica de clase. Como resultado, la capacitación técnica y pedagógica, junto con el apoyo de la administración es necesaria para lograr una integración adecuada de la PDI en las aulas. Según el informe Horizon (Johnson, Adams Becker, Estrada, y Freeman, 2015) para lograr una implantación global de las TIC en los centros educativos es necesario reconsiderar el rol docente, cada vez se le exige más ser experto en las tecnologías educativas y tener las capacidades necesarias para integrarlas en el aula promoviendo un aprendizaje auténtico y digital en el alumnado, aspecto percibido por muchos docentes como una formación paralela.

El uso de la PDI en las clases de ciencias posee el potencial para apoyar el cambio en la forma en que enseñamos, lo importante es que los docentes se familiaricen con las diversas funciones ofrecidas por la tecnología, tienen que estudiar la mejor manera de implementarla para crear un ambiente de aprendizaje positivo que aumente la motivación del alumnado.

El Informe Horizon 2015 (Johnson, Adams Becker, Estrada, y Freeman, 2015) señala como una de las tendencias inminentes en los próximos cinco años el cambio de la función docente propiciado por la influencia de las TIC. Este cambio en parte es debido a los nuevos avances tecnológicos y a su efecto en la evolución pedagógica. Algunos de los cambios a nivel metodológico ya son visibles en los centros educativos españoles, como es la combinación de métodos didácticos tradicionales y virtuales.

CONCLUSIONES

Las conclusiones de este trabajo se ven reforzadas con evidencias obtenidas en estudios de Murcia y Sheffield (2010) y Hennessy, Deaney, Ruthven y Winterbottom (2007), que sugieren que la PDI ofrece beneficios en el aprendizaje de temas científicos, lo que ayuda a los estudiantes a obtener una comprensión más profunda de contenidos y prácticas científicas, aspecto considerado de forma muy positiva por parte de los docentes entrevistados

Todos estos beneficios mejoran la interacción del alumnado, el logro de aprendizaje, la participación activa, la atención y la motivación. Pero encontramos varios factores que desde el punto de vista docente impiden el uso común y eficaz de la PDI, entre ellos la falta de formación en tecnologías y sobre todo en la PDI, apoyo técnico insuficiente, y la falta de materiales educativos bien diseñados compatibles con la PDI para su utilización en aulas de ciencias.

Los docentes participantes indicaron necesitar una formación continua para utilizar el potencial pedagógico que ofrece la PDI y los nuevos recursos tecnológicos que están surgiendo. Muestran frustración por las dificultades técnicas que encuentra, y la limitación de horarios, sería necesaria una mayor implicación por parte de las administraciones, tanto en la dotación de los centros como en los aspectos formativos, para ello es necesario dar oportunidades a los docentes de mejorar su desarrollo profesional ofreciéndoles las posibilidades, como un derecho, de realizar cursos de formación en su horario laboral y en sus propios centros.

La integración y uso de la PDI en las aulas en muchos casos se encuentra obstaculizada por la falta de competencias digitales y modelos pedagógicos en los docentes, así como tener poco claro los objetivos de uso de la tecnología. En pocos años, el uso de la PDI se verá reforzado con la utilización de contenidos en 3D, potenciando la retentiva de los contenidos y estimulando la capacidad de atención de los estudiantes. La PDI generará y aumentará la interactividad de los contenidos en 3D, pues se podrá no solo ver las imágenes, sino tocarlas con el dedo, interactuar con ellas, hacerlas girar, etc… haciendo la dinámica de clase mucho más interesante y atractiva.

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ANEXO

GUÍA DE PREGUNTAS DE LA ENTREVISTA

A. Descripción del profesor/a

Sexo, Edad, especialidad (licenciatura), años de experiencia docente, años de experiencia de uso de las tecnologías en clase, y materias que imparte.

B. Cuestiones

1. ¿En su centro se utiliza algún medio tecnológico para impartir las clases? ¿Cual/es?
2. ¿Usted utiliza algún medio tecnológico en su clase?, ¿Cuál?, ¿Con qué frecuencia?, ¿En qué asignatura/s? y ¿Cómo lo utiliza?
3. ¿A nivel organizativo qué obstáculos encuentra para su uso?
4. ¿Tiene formación acerca del uso de la tecnología?
5. En caso afirmativo ¿lo ha recibido en cursos de la administración o por su propia cuenta?
6. ¿Piensa que necesita más formación en medios tecnológicos?
7. ¿Cree que la administración potencia el uso de tecnologías?
8. ¿Cómo valora las iniciativas y ayudas de la administración?
9. ¿Se siente seguro o inseguro cuando utiliza la tecnología en clase?
10. ¿Cómo definiría usted las TIC? ¿y la pizarra digital?
11. ¿Cuándo tuvo su primer contacto con las Tecnologías?
12. ¿Con qué medios ha trabajado anteriormente (en el pasado)?
13. ¿Qué efecto piensa que ejerce el uso de la tecnología en el aprendizaje de los alumnos?
14. ¿Cree que el disponer de tecnología -como pizarras digitales y ordenadores- influye en el método de enseñanza que utiliza? En caso afirmativo ¿Cómo piensa que influye?
15. ¿Qué posibilidades cree que tienen los medios tecnológicos?
16. ¿Diseña y/o crea sus propios materiales para usarlo con los medios tecnológicos que tiene a su alcance?
17. ¿Qué criterios tiene en cuenta a la hora de seleccionar y/o crear los materiales a utilizar con la tecnología?
18. ¿Utiliza materiales didácticos creados por otras personas (por ejemplo, páginas web, diapositivas, grabaciones de video, etc…)?. En caso afirmativo ¿realiza algún tipo de evaluación de dichos materiales? ¿Cuáles?
19. ¿Qué propondría para una mayor inserción y utilización de los medios tecnológicos tanto por los profesores como por los alumnos?.
20. ¿Cree que el tener una pizarra digital en clase tiene algún impacto en la enseñanza?
21. ¿Ha tenido alguna experiencia con el uso de la pizarra digital en alguna clase? En que ha consistido
22. Si utiliza la pizarra digital ¿cómo la utiliza en clase? ¿para visualizar vídeo, para hacer actividades, para hacer presentaciones de contenidos,....?
23. ¿Cree que el uso de la pizarra digital ofrece ventajas en el proceso de aprendizaje? En caso afirmativo cuales.
24. ¿Piensa que la pizarra digital ha mejorado su manera de dar las clases y el aprendizaje de los alumnos? ¿cómo? ¿en qué sentido?
25. ¿Cómo percibe el uso de la pizarra digital (o en su defecto la tecnología) en el aula?
26. ¿Cree que el uso de pizarras digitales interactivas tiene limitaciones en el proceso de enseñanza?

Received 7-06-2016 /Approved 15-05-2017

Teachers of higher education: Analysis of Brazilian publications in chemistry

Investigaciones brasileras sobre los profesores universitarios de química

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Abstract

Even though it is important, there are only a few works in science education that deal with academic professors as a research subject. Thus, to contribute to the understanding of researches conducted with these professionals who are so important to the development of an academic career, this work presents a document analysis of the papers published in two Brazilian chemistry teaching events: ENEQ and SIMPEQUI. The researches were categorized from 2008 to 2014 and divided according to their levels of education, in which those of higher education were classified with respect to their research subject. The findings showed a deficiency in the research field, since among more than four thousand papers, the university teacher is the research subject in only thirteen. Even though the discussion about the academic professors is necessary, there have been few studies on the subject in the scientific research.

Key words: *educational practice; higher education; ENEQ; SIMPEQUI.*

Resumen

A pesar de su importancia, hoy son pocas las investigaciones que desde la didáctica de las ciencias abordan a los docentes universitarios como sujetos participantes de éstas. Así, para contribuir en la comprensión de las investigaciones realizadas con estos profesionales tan importantes en el desarrollo de carreras académicas universitaria, este trabajo hace un análisis documental de las publicaciones presentadas en dos eventos brasileiros de didáctica de la química: El Encuentro Nacional de Enseñanza de la Química o ENEQ y el Simposio de Investigaciones en enseñanza de la química o SIMPEQUI. Para esto fueron analizadas las publicaciones de estos eventos correspondientes al periodo 2008 a 2014; se hicieron categorizaciones por temáticas o líneas de investigación de acuerdo con los niveles de enseñanza, y para el caso de las del nivel universitario, fueron clasificadas en cuanto al sujeto de pesquisa (el profesor universitario). Lo encontrado muestra una deficiencia en esta área, pues de los más de cuatro mil trabajos revisados, solamente trece tienen al docente universitario como sujeto de investigación. Así, a pesar de ser necesaria la discusión sobre los docentes universitarios, éstos todavía no son participantes de las investigaciones en didáctica de las ciencias o lo son en menor medida.

Palabras clave: *prácticas docentes; enseñanza superior; ENEQ; SIMPEQUI.*

INTRODUCTION

In the studies conducted in the teaching of sciences it is perceived that the focuses of the studies are different; for instance, the curriculum, the programs, the attitudes, the beliefs of kindergarten, primary and secondary teachers, the students, among others. Nevertheless, the question for the role of teacher of higher education in this research context is, "Is he the subject of research or does he only do the research?"

The answer seems clear: Today university researchers investigate the curricula and methodologies of kindergarten, elementary and high school teachers. However, what's the effect this research on training in general of teachers? The Teacher Training in Brazil requires the undertaking of "a major effort in teacher initial and continuing training. Work done on the national board of education showed there is today the deficit of 250,000 teachers, particularly located in chemistry, physics and mathematics disciplines" (ORLIK, 2013, p. 16).

And what's going on with the teacher of higher education? In this sense, Cortela (2013, p. 16) points out that the university teaching has constituted a research field, highlighting in Brazil the papers of Almeida 2012; Cunha 1998, 2006; Ghedin, 2005; Masseto, 2002, 2003; Pimenta; Anastasiou, 2002; Pimenta; Ghedin, 2006; and in the international context, Alarcão, 1998; García, 1999; Gauthier, 1998; Novoa, 1992; Zabalza 2004, among others.

It seems contradictory that today we discuss and do little research on the formation of the teachers in higher education (Cortela, 2013), because there are several demands in which these professionals have to answer to the universities, in particular, the ones who educate other educators.

Even though this occurs, Porto and Mosteiro (2014) say that professors' training and professional development is a key element of quality in the university education. Thereby, it is believed that an assessment of what has been produced by academia and what is disclosed in the chemistry teaching events held in Brazil on the subject is needed.

This survey is important in two senses: first, it allows identification of whether there are lines of research related to the natural sciences university teacher, how these lines are related to what the non-academics focus on the research, how the research impacts on the university to its qualification and continuous improvement; second, it has to do with the theoretical references that identify the formation of the higher education teacher , how the knowledge produced in the studies allows the improvement of the university teacher formation.

One issue to be raised is the lack of studies that reveal research on teachers own practice. An initial assumption is placed, that the research is concentrated in the non-teachers of higher education and students, and there are only a few of them that describe the professor of higher education as its participant.

Therefore, the goal of this study was to reflect on the topic and to analyze the papers published in two of the main Brazilian events regarding the publications on teachers of higher education. Therewith, it was possible to characterize the lines of research addressed regarding the training of teachers of higher education.

In order to begin the analysis, we chose the most significant events on chemistry teaching that took place in Brazil within the last several years. Among the events identified there were the Brazilian Education Symposium in Chemical Education (SIMPEQUI – Simpósio Brasileiro de Educação em Química) and the National Meeting of Chemistry Teaching (ENEQ – Encontro Nacional de Ensino de Química), at the national level. Several regional and local events have been found: Chemistry Education Event (EVEQ – Evento de Educação em Química); Paulista Research Meeting in Chemistry Teaching (EPPEQ – Encontro Paulista de Pesquisa no Ensino de Química); Mineiro Symposium on Chemical Education (SMEQ – Simpósio Mineiro de Educação Química); Paranaense Congress of Chemistry Education (CPEQUI – Congresso Paranaense de Educação em Química); Professionals Symposium of Chemistry Teaching (SIMPEQ – Simpósio de Profissionais do Ensino de Química); among others.

In order to analyze the most significant papers in the area, we chose the two national events. Table 1 shows, in a synthesized way, the characteristics of each event.

Table 1. Characteristics of the events selected for the research.

	Simpósio Brasileiro de Educação Química (SIMPEQUI)	Encontro Nacional de Ensino de Química (ENEQ)
Periodicity	Yearly	Biennial
Organization	Associação Brasileira de Química (Brazilian Chemical Society)	Divisão de Ensino da Sociedade Brasileira de Química (Teaching Division of the Brazilian Chemical Society)
Target audience and goals	Students and other professionals from all over Brazil who are interested in discussing issues related to Chemistry Education	Search for innovative approaches to the educational process through different subjects related to Chemistry Teaching
First edition year	2003	1982
Researched period	2008 - 2014	2008 - 2014
Focused theme in the research period	Chemistry teaching and multiculturalism; Green and sustainable chemistry; sustainability in education; and new technologies in chemistry teaching	Chemical knowledge; formation of a chemistry professor and the challenges of the classroom; chemistry teaching; and the integration between research and school
Researched Issues	7th to 13th	14th to 17th
Type of Work	Oral communication and panel	Oral communication, panel and exhibition of chemistry didactic materials
Total number of works in the analyzed period	1135	2958

Source: Adapted from SIMPEQUI, 2015 e MILARÉ, 2008.

CONCEPTUAL REFERENCES

A reality today is that the university has direct or indirect influence on the formation of teachers at all stages of the educational process. However, how is the actual training done and what are the procedures that the university considers? In other words, does the university evaluate the necessities of the society in the matter of the teacher that it needs and the impact of such training? From the focus of this article, it is clear that the University, and especially its teachers, organize and concentrate on the initial training for elementary and high school levels, mainly to train teachers for these educational levels.

In countries such as Colombia, Mexico, and Venezuela, there are colleges of education or pedagogical universities that grant the titles of Licentiate Degree. The undergraduates of these institutions are teachers who will act in elementary and high schools and, even then, training programs focus on the academic and pedagogical/ didactic contents in their training, but still in a mono-disciplinary, compartmentalized or separated way. On the other hand, there are also masters, doctorates and other programs offered, in which the participants intend to work as teacher of higher education. Thus, the teacher who becomes a teacher of higher education either holds a degree with a masters or a doctorate, or has another professional title beyond the licentiate degree.

So far, we see that the focuses of the training of the teacher in higher education do not seem to be the same as the university's own interest. However, in recent years, we can see a concern for the training of a professor in higher or university education. As Ibernón (2014) says, documents on training, programs, institutional policies and researches on the subject start appearing. However, according to this author, the 1980s was the preparation of the teachers not in higher education, the first 2000 decade may be the decade of training the teacher of higher education, or at least have a greater concern for them in Brazil. The focus of the topic in the higher education teacher training is centered on short courses, which should be revised within the universities policies.

Furthermore, what happens in the research by the teachers of higher education should be revised because, to them, the study subjects are the teachers of other educational levels, curriculum materials, training programs, students of all levels, but the teacher of higher education himself is not the research subject. As Tardif (2004) says, this is not subject knowledge.This can result in a vicious circle that does not allow better training programs for professors of the university.

In this sense, it is proposed that the action research or inquiring model be considered as a model for higher education teachers' own training, but it seems that the teacher does not use it because it calls for a transformation of the elementary and high school teachers. However, will the university teacher change his own practice when researching? Ibernón (2014) proposes this model because: he considers that it allows reflection on what is done uniting the training to a project of change. It should be a process oriented in collaborative decisions, which may establish communication bridges between colleagues, in the interest of the democratic development of the curriculum, the proximity between theory and practice, and a democratic form of research; and it allows working with real education problems.

The teacher of higher education researches, or investigates, producing knowledge about the teaching of the teachers outside higher education, most of the time considering them as objects and not as collaborators or co-researchers. As Tardif (2004) says the elementary school teachers criticize the competence and the value of the administrators; these administrators and teachers criticize the teachers of higher education whose research they consider useless and too abstract; the teachers of higher education, often consider themselves guardians of knowledge, they are full of their own knowledge and criticism of professional teachers because they think that we are adhering to the traditions and routines (p.179).

Doing research about the university professor (of his teaching, his beliefs, his didactics) is necessary, not as a criteria of evaluating the quality of the teacher, which most often is focused on academic production, but because, according to Cortela (2013), he/she rarely appreciates the act of teaching, not giving importance to the didactics and pedagogical dimension.

METHODOLOGY

The methodology used was qualitative, characterized by the depth of the data and interpretative richness, which were contextualized within the scope of chemistry education events in Brazil. Although the events are national, they have specific features and ways to systematize the work. In the case of ENEQ jobs are already organized by themes, namely: concepts; science, technology and society; curriculum and assessment; environmental education; teaching and learning; teaching and culture; teaching and inclusion; non-formal spaces; experimentation in teaching; teacher training; history, philosophy, sociology of science; language and cognition; educational materials; display of teaching chemical materials; public policies; information technology and teaching communication.

Therefore, the first step of the analysis was to separate the papers of SIMPEQUI in the mentioned themes, getting a standardization of both events. Then, we classified the work according to the levels of education, namely: elementary school (ES), high school (HS), higher education (HE), non-formal education (NFE) and others (O). This last category was created to classify the papers that had no explicit level, as in the case of philosophical discussions.

As the focus of interest is higher education, what was analyzed was the works classified at this level and identified the research subjects. Beyond that, we detailed the searches according to the professional profile and the lines of research of the authors from the articles whose subject was professor of HE.

RESULTS AND DISCUSSION

The first categorization was made with respect to the themes of the event. The results show that most of the work is about "teaching and learning" – representing approximately 25% of the research presented at both events. The categories that appear next are, respectively: teacher training; experimentation and curriculum; and assessment.

Then, the papers were classified according to the levels of education ES, HS, HE, NFE and O. Table 2 presents in detail the quantification of the work with respect to the separation by the level of education. What we found when analyzing the themes by level was that the higher education works appeared largely in both the SIMPEQUI and the ENEQ, on the theme "teacher training". Another major part of the HE works are in "teaching and learning" and "experimentation" and few of them are distributed in other categories.

Table 2. Quantification of SIMPEQUI and ENEQ works by categories of educational levels from 2008 to 2014.

	Year	Amount	ES	HS	HE	NFE	O	Total
SIMPEQ	2008	Absolute	4	27	21	1	0	53
		Percentage (%)	7,5	50,9	39,6	1,9	0,0	100
	2009	Absolute	3	55	22	2	0	82
		Percentage (%)	3,7	67,1	26,8	2,4	0,0	100
	2010	Absolute	19	102	40	2	0	163
		Percentage (%)	11,7	62,6	24,5	1,2	0,0	100
	2011	Absolute	11	68	46	0	0	125
		Percentage (%)	8,8	54,4	36,8	0,0	0,0	100
	2012	Absolute	11	120	52	0	0	183
		Percentage (%)	6,0	65,66	28,4	0,0	0,0	100
	2013	Absolute	35	172	55	1	0	263
		Percentage (%)	13,3	65,4	20,9	0,4	0,0	100
	2014	Absolute	32	147	83	4	0	266
		Percentage (%)	12,0	55,3	31,2	1,5	0,0	100
ENEQ	2008	Absolute	19	357	47	25	14	462
		Percentage (%)	4,1	77,3	10,2	5,4	3,0	100
	2010	Absolute	16	408	123	32	13	592
		Percentage (%)	2,7	68,9	20,8	5,4	2,2	100
	2012	Absolute	23	700	126	35	25	909
		Percentage (%)	2,5	77,0	13,9	3,9	2,8	100
	2014	Absolute	27	776	106	55	31	995
		Percentage (%)	2,7	78,0	10,7	5,5	3,1	100
TOTAL	Period	Absolute	200	2932	721	157	83	4093
		Percentage (%)	5,0	72,0	17,0	4,0	2,0	100

Source: Authors.

By analyzing Table 2, we notice that the major focus of Brazilian research in the chemical education area is targeting high school (72%), which is perhaps related to the growing initiative of PIBID (Programa Institucional de Bolsas de Iniciação a Docência, which in English means: Institutional Program for Grant in Teaching Initiation – from CAPES). In the featured column on Table 2 we find the numbers of papers related to each year for HE, considering that this is the second most discussed level in the polls. Note, also, that is an oscillating theme, where the number of published works varies up and down (see percentages highlighted in HE column).

As the focus of interest is higher education, we analyzed the works classified at this level to identify the research subjects. Thus, according to Table 2, from the 4093 works analyzed, 721 are related to HE (17%). Among this total, as illustrated in Figure 1, only 13 papers have researches focusing on the teacher at this level, while the rest focus on students and document analysis.

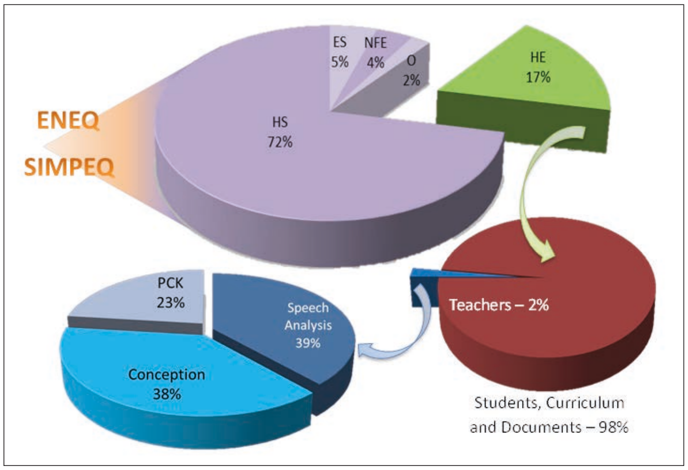

Figure 1. Outlining of the papers related to higher education professors. Source: Authors.

Also as shown in Figure 1, from thirteen papers (100%) on the higher education professors (one of SIMPEQUI and twelve of ENEQ), five (38%) address the conceptions of teachers about concepts, such as: chemical phenomenon, enzyme kinetics, experimentation, playfulness, teacher training, environmental education and nature of science. Three surveys (23%) are on the pedagogical content knowledge (PCK) and five (39%) deal with speech analysis (semiotics) through gestures for teaching organic chemistry. The description of the work is on Table 3.

The five works that address the theme about discourse analysis are the research group led by Professor Eduardo Fleury Mortimer (UFMG). This professor works in the research line of "elaboration of concepts in science and teaching", "training of chemistry and science teachers", "language and cognition in the classroom", "teaching and learning chemistry and science", "discursive interactions in science classroom", "discursive interactions in science classroom" (MORTIMER; MACHADO, 2013). Although not specifically dealing with the teacher of higher education as a research area, Mortimer brings great contributions to this research subject, and it is possible to infer that he might be a reference in the area.

Three other works that address the PCK theme are of Professor Carmen Fernandez (USP – University of São Paulo), whose research line are: "chemistry teacher training", "knowledge of chemistry teachers", "knowledge base for teaching", "pedagogical content knowledge", "professional development" (FERNANDEZ, 2015). Again, despite not having a line or specific training to deal with higher education teachers, Fernandez addresses the issue of the PCK, which is a recent topic of research in Brazil, suggesting that the first works on the HE of this area are beginning to be developed.

The other works in this category have different authorship. Two of these works are from the same author: Lisandro Bacelar da Silva, Master in Education, History and Philosophy of Sciences from the Federal University of Bahia (UFBA) and an expert on higher education teaching by UNIFACS. They show a concern of the researcher with the teacher of higher education as a research subject.

Through the analyses done, we note that there is a low amount of research focused on the higher education teachers, because from a total of 4093

Table 3. Papers focusing on the teacher of higher education in both events.

Year	Title	Category
2010	Multimodal language: the classes of the Higher Education Professor	Speech analysis
2012	Conceptions of teachers of higher education about the function of experimental activities in a course of licentiate degree in Chemistry	Conception
2012	Pedagogical Content Knowledge of an experienced teacher in a discipline of General Chemistry at the higher education level	PCK
2012	The pedagogical content knowledge of a teacher of Higher Education on the concepts of “Enzyme Kinetics”	PCK
2012	Conceptions of Higher Education Teacher in Chemistry about the implications of the graduate programs in the teacher training	Conception
2012	Multimodal interactions in Higher Education Chemistry classes	Speech analysis
2012	Semiotic analysis of the ways in Higher Education Chemistry classes.	Speech analysis
2012	The conceptions of the teachers of the courses of licentiate degree in chemistry about the concept of chemical phenomenon	Conception
2014	Aspects of the formative action of higher education teachers incorporated into the PCK of its undergraduates	PCK
2014	Deictic gestures in higher education chemistry class	Speech analysis
2014	The interaction of recurrent gestures with other semiotic ways during the sharing of meanings in classes of organic chemistry	Speech analysis
2014	Conceptions of chemistry teachers about the teaching of green chemistry: an investigation*	Conception
2014	Conceptions of chemical phenomenon of teachers who teach specific subjects in a licentiate degree chemistry course	Conception

*The only paper of the SIMPEQUI on the analyzed period. Source: Authors.

works analyzed, only 0.3% have this research subject. The main references are Mortimer and Fernandez, in the areas of discourse analysis and PCK, respectively. This implies that there are only a few research works with a focus on higher education teachers and they need further development.

It is important to continue inquiring about the trends that are in the research teachers of higher education because as argued several authors (S. da Silva and A. de Oliveira, 2009 apud Orlik, 2013) large number of teachers working in undergraduate courses do not have didactic training. For many, the choice of a profession at the university is based on career search as a researcher and not in its function of teaching. It’s because of “systemic processes of training science teachers still oriented to different levels of teachers to university” (MOSQUERA, 2014, p.63)It is necessary to know how the professor is involved in the new research lines that he uses when he asks the teacher, for example, about epistemologyor PCK as a way to represent and differentiate their pedagogical / didactic knowledge of the discipline (GUISASOLA, et al, 2014; PARGA; MORA, 2014).

CONCLUSIONS

The teachers of higher education are a research object that requires more work in several areas. As explained throughout this writing, few studies deal with the teacher of higher education as the subject of the research. Through the executed analysis in two major events in the area of chemistry teaching, we notice that there really are deficiencies in the researches that focus on the higher education teacher.

The results show that there is a gap in the research with this theme and that further research is necessary. Besides that, in Brazil, the main references in the area of chemistry teaching that investigate the teachers of higher education are Mortimer and Fernandez, within the discourse analysis and the PCK areas, respectively.

It is necessary that the higher education teacher begin to value his/her act of teaching, giving the necessary importance to the didactic and pedagogical dimension. Moreover, the teacher should allow himself/herself to be part of his/her own research, being a contributor to the expansion of his/her research area of expertise.

ACKNOWLEDGMENT

To the chemistry teacher César Felipe Vizioli for the help with the data and to Dr. Beatriz Cortela for the text corrections and support.

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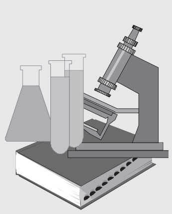
Received 11-05-2016 /Approved 15-05-2017



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Role-playing for learning to explain scientific concepts in teacher education

Juego de roles para aprender a explicar conceptos científicos en formación de profesores

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Abstract

This study explores role-playing as a method for learning to teach scientific concepts through explanation during teacher education. The participants were 38 biology and primary school science student teachers from three Chilean universities. They were involved in the simulation of teaching, playing the roles of teachers, pupils and assessors in small groups; they mutually assessed each other and implemented their explanations. Fourteen role-playing sessions were analyzed including three focus groups at the end of the experience. The explanations were analyzed in their structural and representational elements, which could involve aspects of nature and or history of science. Qualitative analysis was conducted following the processes of Grounded Theory. Results showed post explanation to be more structured and richer in resources. The participants recognized and identified their explanations as models that might change. However, they did not incorporate elements related to history or nature of science. This study concluded that although role-playing of teaching and peer assessment are useful social activities for promoting rehearsal of teaching practice - and improving some aspects of explanations - a different strategy is needed for incorporating all the elements. The implications for initial teacher education and science teaching research are discussed.

Keywords: *role-playing, explanations, student teachers*

Resumen

Este estudio exploró la metodología de juego de roles en formación inicial de profesores para aprender a explicar conceptos científicos. Participaron 38 estudiantes de pedagogía en biología y ciencias para primaria, provenientes de tres universidades chilenas. Ellos desarrollaron simulaciones de enseñanza, jugando roles de profesores, alumnos y evaluadores en pequeños grupos, se evaluaron formativamente entre pares e implementaron nuevamente sus explicaciones. Catorce sesiones de juego de roles y tres grupos focales fueron analizados. Las explicaciones fueron codificadas en sus elementos estructurales y representacionales que podían incluir aspectos relacionados con la naturaleza y/o historia de las ciencias. Se condujo un análisis cualitativo basado en la Teoría Fundada. Los resultados mostraron que las explicaciones luego del juego de roles fueron más estructuradas, ricas en recursos, y los participantes las visualizaron como modelos sujetos a cambios. Sin embargo, no incorporaron elementos relacionados con la naturaleza o historia de la ciencia. Se concluye que aunque el juego de roles en la formación de profesores es una metodología formativa útil para aprender a explicar conceptos, que apoya el ensayo y práctica de enseñanza, una estrategia diferente se requiere para incorporar dichos elementos. Implicancias para la formación docente y la enseñanza de las ciencias son discutidas.

Palabras clave*: juego de roles, explicaciones, estudiantes de pedagogía*

INTRODUCTION

There is much public discussion concerning the need to develop the quality of teacher education and knowledge based on changing their conceptions (Kember & Kwan, 2000). In this field, it has been suggested that different types of assessment should be implemented to encourage teachers to self-reflect on their teaching and adjust their practice (Borman, Mueninghoff, Cotner, & Frederick, 2009). The difficulties in the shift from the student role to the teacher role are well known (Fernandez, 2010, Jian, Odel, & Schwille, 2008), as the fact that early microteaching experiences can help student teachers to develop individually teaching competences (l'Anson, Rodrigues, & Wilson), for instance, rehearsing to teach through simulated contexts (Inoue, 2009; Lu, 2010; Ostrosky, Mouzorou, Danner, & Zaghlawan, 2013). However, identifying the reasons for their efficacy remains under-researched. In science education only a few studies have reported the development of teaching practices during teacher education based on peer assessment or feedback.

Peer collaboration has been explored as a method of developing practical skills during initial teacher education, as part of peer learning (Cabello & Topping, 2014; Lu, 2010). Peer assessment is a procedure by which students evaluate the level, value and quality of the work/performance of other students of equal status, usually incorporating feedback (Topping, 2010). Moreover, it has been noted that peer assessment encourages more participatory culture (Kollar & Fisher, 2010) whilst serving to analyze and identify good practices in teacher education (Sonmez & Can, 2010), and helping teachers with the problem of giving individual attention to members of large groups (Orlik, 2010). For some authors, peer assessment is a social process that works mainly because of the feedback received. From their viewpoint, feedback is the component that contributes most to the learning experience[1]. Nonetheless, the few studies conducted in teacher education do not offer robust evidence for this assertion, which implies the need for a profound investigation into how teaching skills are acquired during this preparation and peer learning (Koziol, Minnick and Sherman, 1996).

Otherwise, constructing concepts through explanations and models is one of the teaching practices that, when performed competently, will likely improve students learning; thus it is a central skill to develop during initial teacher education (Ball, Sleep, Boerst, & Bass, 2009). In fact, among Chilean science in-service teachers, explanations are the most commonly used strategies to illustrate concepts (Preiss, Alegría, Espinoza, Núñez, & Ponce, 2012), but with one of the lowest performance indicators in the national evaluation for in-service teachers (Gobierno de Chile, 2013).

In this study, teacher explanations are understood as a coherent unit by which the teacher connects representational devices to guide student comprehension (Geelan, 2003), including not just verbal aspects, but also non-verbal, representational and experimental elements - and the connections between the students' and the teacher's ideas (Cabello & Topping, 2014, p. 87). Teacher explanations do not necessarily contradict the inquiry views of teaching or constructivist learning theories (Geelan, 2012). In fact, Orlik (2010) asserted that one of the most important purposes of explanations is they serve teachers for choosing and representing the subject matter. Devices such as metaphors, analogies and models could stimulate new inferences and insights, and advance the conceptual understanding of phenomena (Glynn, Taasoobshirazi, & Fowler, 2007). Through examples, images or graphs students can create mental images (Ogborn, Kress, Martins, & MGillicuddy, 1996), which, as well as schemas, are useful supportive signals for their learning. Likewise, demonstrative experiments are powerful tools for learning when they are connected with students' daily life or experience (Orlik, 2010). It is also worthy explaining by addressing the common misconceptions in order to avoid these later on (Thompson & Logue, 2006). Moreover, teacher explanations express implicit messages on the nature of science (Edgington, 1997) and, explicitly, about history of science for contextualizing the ideas (Abd-El-Khalick & Lederman, 2000).

Regarding those elements, research has been centered on the explanations that students construct to demonstrate their knowledge (i.e. Camacho, 2012; Ruiz-Primo et al., 2010; Sandoval & Reiser, 2004), and not on teacher explanations. A meta-analysis by Geelan (2012) searched for the terms: science, teach and explain on the ERIC database. It resulted in 1,362 hits; but fewer than 35 of these articles were about aspects of teacher explanations, mainly analogies. Thus, the research potential in this area is clear and overlooked (Charalambous, Hill, & Ball, 2011; Geelan, 2012).

This study explored role-playing in learning to explain scientific concepts in student teachers, based on the idea that formative peer assessment might enrich their explanation elements.

1 See for example Gielen & De Wever (2012), Liu & Carless (2006), Thurlings, Vermeulen, Bastiaens, & Stijnen (2013), Van der Pol, Van den Berg, Admiraal, and Simons (2008).

METHODS

The participants were 38 student teachers from three Chilean universities during their final year of undergraduate education in the field of Biology and primary school science. They participated in fourteen sessions of simulated microteaching of scientific concepts as an intervention in which they were volunteers, playing the following roles: teacher, pupils and assessors. The sessions were recorded and transcribed verbatim.

The intervention(s) had the following format: two sessions introduced the requirements for participating in the study, so that the formative peer assessments would be carried out properly (respect, constructive criticism, etc.). The participants signed an informed consent. Furthermore, a session was dedicated to analyzing a class video to rehearse peer assessment and the feedback that a young teacher would likely receive. Subsequently, the initial role-playing and peer assessment was conducted in two sessions, where the student teachers developed microteaching episodes of scientific concepts of their choice and provided feedback to one and another. Some of the concepts chosen were; the structure of the Earth, evolution, electric charge, and the transformation of matter.

After the first round of role-playing, two sessions were held in which the participants discussed their practice models and which ones could be improved. This discussion covered some guidelines from the cognitive model for science teaching (Jorba & Sanmartí, 1996), such as the incorporation of students' misconceptions when introducing new perspectives, contextualizing the explanation, inquiry and application/transference of the concept to other fields. The participants discussed these ideas and agreed on some common points/criteria in which their explanations could improve. Following this, two sessions were dedicated to the second round of role-playing and peer assessment. During these assessments, the concepts that the participants chose for their explanations included: the Earth's movements, hormonal cycles, electrical current flow in a circuit, and atomic structure, among others. It should be noted that the participants did not have access to the rubric used by the researchers to analyze their explanations, in order to avoid a possible improvement guided only by the need to fulfill the criteria of the test, and give them the opportunity to perform based on self evaluation and the effects of peer assessment on their practice. The explanations were analyzed in three main areas; structural elements – including clarity; coherence and consistency; organization; conceptual precision; completeness; connection with students prior ideas-, elements of the nature of science - observed through the use of analogies, metaphors, simulations, experiments or models; use of examples, images or graphs mentioned as representations; use of representational gestures; treatment of students misconceptions as learning opportunities - and elements of history of science. Table 1 describes, in general terms, each criteria.

Table 1. Components examined in student teachers explanations of scientific concepts

Component	Description
Clarity	Proper use of explanatory language
Coherence and consistency	Connection between different parts that configures the explanation as a coherent unit
Organization	Structural progression of explanation
Conceptual precision	Adherence to actual scientific models and theories
Completeness	Explanation's sufficiency in terms of teaching objectives
Connection with students' ideas	Link between explanation and students' prior ideas or experiences
Use of analogies, metaphors, simulations, experiments or models	Proper application of tools to help students deconstruct the concept
Use of examples, images or graphics	Proper application of tools to help students interpret the concept
Use of representational gestures	Gestures to represent concept, intonation or inflections in voice
Treatment of students misconceptions as learning opportunities	Usage of errors in understanding of concept as source of inquiry, opportunity for learning and/or evaluation
Incorporation of history of science perspective	Usage of elements related with history of science

At the end of the experience, three focus groups were conducted to gather student teachers perceptions about the methodology. A qualitative approach was used for data analysis, following two of the coding types by the Grounded Theory: open and axial (Glaser, 2004) aided by NVivo software for ordering data (QSR, 2011). Researcher triangulation was accomplished to work towards reliability (Patton, 2001).

RESULTS AND DISCUSSION

From the participants perspective, role-playing allowed the change in their conceptions about science teaching through explanations as a consequence of reflecting on their practice; confronting the familiar theories about teaching with practice within microteaching - identifying their strengths and weaknesses. Discussing about good explanation was important for them, as mentioned in the following extract. However, a more powerful effect is envisioned if they would have known the analytical framework of the explanations, but this was avoided for the study design characteristics.

"I think the creation of criteria was fundamental. Because now I check it in my mind, and I am going to the criterion I've formulated. Because the things we learned at university, after… we do not remember it, but when you create a criteria, it is different, because you think "let's see how I taught the lesson"". (Interview 1:11)

They mentioned that playing the role of teacher and receiving feedback from peers was a key factor for changing their focus of analysis towards their practice, and, consequently, self-regulating it. This change was projected in their future real teaching and some of the participants proposed sharing the experience with student teachers in earlier years as a potential transference of learning. Other participants suggested running role-playing within their future schools, arguing that they had learned from one another in this activity and it can be also useful between colleagues.

Our analysis led to the following interpretation, feedback was not the only element encouraging changes in the participants' practice of explaining, but two psychosocial processes enhanced the changes: projection and reflection. When the participants took the role of assessors they projected their own decision-making on the peer performance and the participant performing the role of teacher reflected what the assessors would do in a similar teaching situation. Figure 1 shows an interpretative model. Each line represents an element of the model for this role-playing using assessment and feedback, organized from (a) to (h).

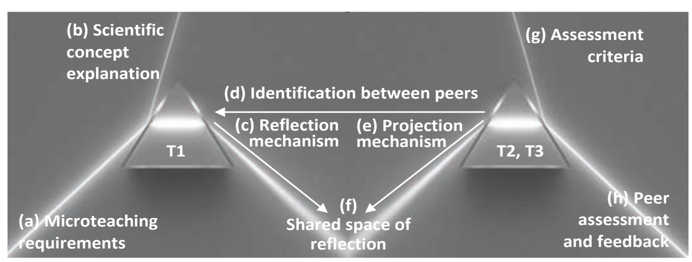

Figure 1. Model of projection and reflection mechanisms in Peer Assessment

(a) Student teacher 1 (T1) is required to simulate a microteaching episode and (b) creates an explanation of a scientific concept. The T1 prism represents T1's performance. (c) As in a mirror, reflection process operates: T1's practice, decisions and mistakes reflect what other teachers (T2, T3) would do. (d) Teachers in the assessor role (T2, T3) are identified with T1's practice because it is performed by a peer and (e) projection mechanism runs: assessors mentally project their own possible decisions and practice on the participant in the role of teacher performance. Thus, both refractions join in the middle in a shared space of reflection (f) on teaching experiences – and hence perceived possibilities and general understanding are increased. Lastly, T2 and T3 use assessment criteria (g) to base their comments on and generate peer feedback (h) about T1's performance. However, this feedback speaks not only about T1's performance, but also about T2 and T3's projection onto it and their teaching experience and expectations about what real teaching will be in the future, including the representations of the challenges that pupils will bring into the classroom.

Regarding student teacher explanations, results showed that after peer assessment, on the one hand, their explanations were more structured and contained more resources, whilst more explicitly mentioning elements related to the nature of science. This meant effectively that their explanations were clearer in terms of language and also more accurate in terms of scientific terminology. Moreover, the participants pointed out their explanations as models that might change. The explanations were more connected with simulated pupils' ideas and experiences, and contained more analogies, metaphors and demonstrations after role playing and peer assessment, which are powerful representational elements for learning (Ogborn, Kress, Martins, & MGillicuddy, 1996; Glynn, Taasoobshirazi, & Fowler, 2007). No variation was found in the explanations coherence, consistency, organization and completeness because they were already well developed. Otherwise, considering students misconceptions as an opportunity for learning and incorporating elements related to the history of science showed the lowest performance and almost no improvements. These elements were orientations in the science teaching courses, thus, an improvement was expected as in the other ones. The participants mentioned that changes in their initial teacher education curriculum must be made, such as including workshops about history of scientists and their discoveries or simulated lessons with real pupils and their ideas. This fact revealed that although role-playing of teaching could be a useful social activity for promoting rehearsal of the explaining practice, improving explanation resources for connecting the concepts with teaching the history of science as well as using misconceptions for learning need a different strategy. These are relevant for good teaching (Abd-El-Khalick, & Lederman, 2000, Thompson & Logue, 2006), because they illustrate science as a human and dynamic construction, open to reformulations, and increase students' motivation for learning it in spite of possible mistakes. Actually, taking misconceptions as a source of learning might promote students' perseverance, viewing how knowledge is constructed.

Finally, regarding peer feedback and assessment; Van der Pol, Van den Berg, Admiraal, and Simons (2008) and Gielen & De Wever (2012), argued that effective peer feedback depends on the skill of the assessor in giving feedback. The present research supports this. Significant learning would be achieved not only as a consequence of the assessor skills when giving feedback, but also in the internalization and enactment of the assessment criteria. This process is crucial for self-regulated learning and for teaching science in daily life. This means that in effect the design of assessment criteria in teacher education for peer assessment and feedback would contribute to teachers developing an internalized self-assessment tool; through assessing and giving feedback to others they can become their own assessors at the moment of teaching in schools, taking decisions to improve their performance moved by their own self-criticism.

Some authors have stated that peer feedback provides the most important learning component of peer assessment (Liu & Carless, 2006; Thurlings, Vermeulen, Bastiaens, & Stijnen, 2013). However, the present research showed that discussing assessment criteria and its application in providing peer feedback was the crucial element in the contribution to the further internalization of criteria and generalization of behaviors into the teaching context, more so than receiving feedback. In other words, peer feedback might be the engine of student teacher improvements, nonetheless, the internalization of assessment criteria - designed for peer feedback - perhaps is the crucial element for promoting improvement in reciprocal role-playing.

CONCLUSIONS

In the field of changing teacher thoughts and perceptions, one of the missing elements was the potential role of peers. In this argument, although the importance of collaborative learning is clear (Orlik, 2010), the available studies in peer assessment do not offer a conceptualization of the restructuring process itself or what roles the peer assessment elements performed. The present research proposed a model based on reflection and projection mechanisms and several other factors described by the participants. The research reveals the current gap in knowledge about the conditions that make this process effective in teacher education. Nevertheless, as this study did not involve typical experimental control and test groups, it is not possible to establish causality, which might be considered a limitation. Even so, the results added new elements to the comprehension of student teachers thoughts and practice.

This study revealed that role-playing and peer assessment of teaching are useful for promoting not only rehearsal of teaching practice, but also eliciting student teachers expectations of the challenges they will face as teachers. This rehearsing to teach might help student teachers becoming reflective practitioners through discussing, projecting and reflecting their performance with peers. In this study, discussions resulted in productive inputs, which might have led to an individual revising their particular form of practice by recognizing and pointing out their explanations as models, which enriches the ideas of l'Anson, Rodrigues, & Wilson (2003) on this.

Otherwise, role-playing as a social process facilitated the negotiation of meaning (Clarke, 2002) and internalization of assessment criteria, which is crucial when promoting understanding and enactment of high quality performance in the transition into real teaching (Stiggings, 1991). In this study, role-playing promoted regulation of learning between student teachers and changes in student teacher conceptions about teaching. This is relevant because changes in the quality of teaching are unlikely to happen without changes to teacher conceptions (Kember & Kwan, 2000).

The broad scope of this research has implications for practice beyond the context of the Chilean teacher education. This study outlines methodologies that consider the educational power of peers, which distributes responsibility of teaching-learning among the learners themselves. This can help not only student teachers, but also in-service teachers to assume a more professional role in their teaching and a sense of ownership of their learning, through constructing criteria to peer and self-assess their work. Likewise, the explanation elements that are easier and more difficult to change are a point of consideration for stakeholders in teacher education for directing resources and time, offering curriculum emphasis such as in history of science.

In terms of immediate further research, this study suggests investigating different effects of peer feedback combined with other techniques derived from the critical analysis of teacher practice in weak areas, like incorporating an historical perspective in science teaching. For instance, comparing groups that receive peer feedback with others that have peer *and* tutor feedback would be relevant to understand development of teachers' conceptions and practice. This possibility is an open gate for new researchers.

Acknowledgements

Conicyt PAI's national research funding program for returning researchers from abroad (2013 call for proposals, project 821320002).

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Received 5-10-2016 /Approved 15-05-2017

Factors influencing the adoption of ICT by universities from the technological infrastructure dimension

Factores que influyen en la adopción de las TIC por parte de las universidades desde la dimensión tecnológica

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Abstract

Given the need for the Higher Education Institutions (HEI) to adopt, adapt and appropriate the Information and Communication Technology (ICT) to transform their process of teaching – learning, this study was conducted to identify the factors that influence this process, from the technological dimension. For the study it was necessary to perform a conceptual theoretical review of the past 10 years based on various literature sources. The results show a better theoretical understanding of the elements from this dimension that must be taken into account when incorporating ICT by the HEI. The factors found are related to: Personnel, Infrastructure and Strategic Management. These, in turn, are divided into sub-factors. The first group consists of: ICT management (technical support) and users support and competency (teacher training). The second group consists of: hardware, software and networks. Finally, the third and final factor is composed of: technological prevention and technological improvement.

***Key words** - factors, ICT appropriation, university, education, technological infrastructure.*

Resumen

Dada la necesidad que tienen las Instituciones de Educación Superior (IES) de adoptar, adaptar y apropiarse de las Tecnologías de Información y Comunicación (TIC) para transformar sus procesos de enseñanza – aprendizaje, se realizó este estudio a fin de identificar los factores que influyen en este proceso, desde la dimensión tecnológica. Para el estudio fue necesario realizar una revisión teórica conceptual de los últimos 10 años, basándose en diversas fuentes bibliográficas. Los resultados encontrados evidencian una mejor comprensión teórica de los elementos que, desde esta dimensión, deben tenerse en cuenta al momento de incorporar las TIC por parte de las IES. Los factores encontrados se refieren a: Personal, Infraestructura y Gestión Estratégica. Estos a su vez se dividen en sub-factores: el primer grupo se compone de Gestión de TIC (soporte técnico), usuarios y alfabetización (formación docente). El segundo grupo se compone de: hardware, software y redes. Finalmente el tercer y último factor se compone de prevención tecnológica y mejoramiento tecnológico.

***Palabras clave:** factores, apropiación TIC, universidad, educación, infraestructura tecnológica.*

INTRODUCTION

The exponential growth of ICT has created new and unimaginable opportunities and educational alternatives that provide ubiquitous features and continuous accessibility and flexibility of interactivity to the learning, allowing in turn improving the teaching - learning process. These potentials and qualities are recognized by the international community (Sandia Saldivia, 2015). However, the responsiveness of Higher Education Institutions (HEIs) and flexibility against the momentous changes is a complex problem, because the challenge goes far beyond the simple addition of technologies. This represents a redefinition, reorganization and planning of educational processes, and therefore the HEIs themselves.

It is important to clarify a number of quality factors that must be present in the process of appropriation of ICT in higher education institutions. These factors can be grouped into three broad areas: organizational, related to the management and organization of the institution; academics, referring to all the elements that include the teaching - learning process; and technology, which involves everything that relates to the operational and functional part (Sandia Saldivia, 2012).

This paper presents a documental review of the theoretical and conceptual elements that are part of the process of adoption and appropriation of ICT from the technological dimension. The study was based on a documentary research, in which a rigorous classification of information, considering the ideas, theories, concepts or proposals of the authors, taking into account the principles of reliability, objectivity, consistency, relevance, completeness and representativeness was conducted, in order to generate a conceptual framework to form a body of ideas on the factors and sub-factors technology.

METHODOLOGY

According to Arias (2012), documentary research is a process that is based on the search, retrieval, analysis, criticism and interpretation of data and information obtained and recorded by other researchers in various documentary sources, in order to generate new knowledge.

The organization of the information collected consisted of a division by categories, under the criteria of objectivity and relevance of the factors that were considered most important in the documents found. These help out to generate a theoretical construction on the main factors affecting the adoption of ICT in the HEI, based on inference and interpretation of this information, which ultimately led to the results, that clearly explain each of these factors. It is worth noting that parallel to this, there have been two similar works, focused on the organizational and teaching – learning dimensions, respectively.

First, some international models for the adoption of ICT from the technological perspective were conceptualized. These models allow, in a methodical way, navigate through the different phases of the way of the adoption of ICT in higher education institutions.Following is a brief overview of each model.

ACL SPLA model *(e-learning positioning statement).* This model aims to diagnose the maturity of the institution regarding the incorporation of ICT. It was designed as an aid for institutional strategic planning and as a support for the process of improving institutional quality. It is used for the management and leadership of the e-learning courses at NIACE *(National Institute of Adult Continuing Education).* (NIACE, 2007).

Among the reference models in terms of appropriation of ICTs, it is also the EFMD –CEL *(European Foundation for Management Development)* model. This model is recognized as a reference in quality certification processes aimed to the management of programs that incorporate education learning based on ICT. It allows to evaluate what is happening in the organization from the perspective of the program, pedagogy, economics, technology, organization and culture, using criteria, indicators and standards, in order to improve the quality of the programs offered supported by educational technology (EFMD CEL-Accredited, 2006).

On the other hand, it is the CAPEODL model *(Comprehensive Approach to Program Evaluation in Open and Distributed Learning)* proposed by Badrul Khan (2004), which combines the knowledge proposed in his model P3 *(People-Process-Product Continuum in e-learning),* presenting a procedurally lists of several products for the seven stages of *e-learning.* In a second part, it refers to the framework of virtual learning serving as a diagnostic tool to develop a comprehensive approach to the assessment of learning programs (Morrison, 2003).

Finally, there is presented the Proposed Methodology for Transformation Presence to Virtual or *e-learning* Programs, of the Ministry of National Education of Colombia (MEN) (Ministerio de Educación, 2010), which allows higher education institutions to implement virtualization projects carried out by the *e-learning* 2.0 association agreements.

This model is basically aimed at the transformation of classroom to *e-learning* programs, and describes three dimensions: organizational, technological infrastructure and teaching - learning (Castillo et al, 2007).

Organizational dimension. This dimension indicates the need to implement structural changes to prepare and condition the organization towards the incorporation of ICT. It requires a diagnosis for classifying at what level the institution is, and then proceeds to the analysis of the environment in which e-learning will take place. For this dimension, the MEN methodology says that it is also necessary to consider strategies and lines of work to allow concrete actions to provide high quality programs (Castillo et al, 2007).

Technological infrastructure dimension. In this dimension it is considered that the appropriate technological infrastructure is a fundamental requirement for technology-based instruction. This means having networks, hardware and software, and technology support staff appropriate for faculty members. The technology infrastructure must also deal with administrative and academic needs (Bates, 2001).

Teaching-learning dimension. In this dimension, the MEN methodology perceives ICT in education as an essential component of the teaching, learning and assessment processes. It indicates that the formative intent is expressed in the methodological diversity of teaching and learning and in the innovative teaching, outside the traditional standards. Thus, ICTs allow a key dimension for any domain of personalized learning (Castillo et al, 2007).

To transform classrooms to virtual or e-learning programs, from the perspective of the technological infrastructure, the methodology of MEN proposes a procedure in which the first step should be to make a diagnosis to determine the requirements of the institution (physical facilities, network services, and personnel support) (Castillo et al, 2007).

As a second step, it should consider the Learning Management System or LMS to facilitate *e-learning* services. These LMS platforms offer integrated learning environments that provide functionality, usability, use of standards, scalability, security and reliability (Castillo et al, 2007). Then, it must move to quality assurance and service delivery systems that support various processes within the institution. It requires offer to the virtual students the facility to access their course materials anytime, anywhere safely (Castillo et al, 2007). Finally, it is required document the preparation of the technology infrastructure where the requirements of today's server infrastructure, telecommunication and technological model for *e-learning* are specified and describe technological support systems (Castillo et al, 2007).

According to the MEN model, the technological dimension becomes a keystone for the institution; it undertakes to ensure the appropriate and relevant tools and technologies to respond to e-learning teaching process raised. This must force to promptly provide the intellectual, technical and technological capital needed to enable the organization, monitoring and measurements required by the communicative and educational dimensions and ensure interactivity, mobility, connectivity and interaction between different people and various elements of the learning environment (Universitaria Virtual Internacional, 2013, p. 52).

RESULTS AND DISCUSSION

Upon the review of the theoretical and conceptual elements, present in the different models studied and specifically in the MEN proposal, and the analysis of the criteria raised by them, focusing on technological infrastructure dimension, there were identified the factors and sub-factors that may conform this dimension. The major factors found are: personnel, infrastructure and strategic management. Below is presented a description of each factor and their respective sub-factors, which were determined according to the authors studied.

Personal factor

This factor aims to be a teaching support from the technological dimension, where an organizational structure, that combines a mixture of centralized and decentralized strategies with individual faculties and departments are recommended (Bates, 2001).

Bates (2001) further states that "…to teach with technology a degree of skill is required, and this requires training not only on technical issues, but also in educational practice. Training should be integrated into the course development process, and this may help the project management model" (p. 03). For this reason, Sancho Gil (2011) notes that it is important to have, not only an infrastructure required to carry out learning experiences worthwhile, but provide to teachers the tools to have optimum working conditions.

The importance of this factor can be seen in the proposal for the incorporation of ICT at the University of Nariño, where it considers the human talent available to use, adopt and develop IT tools; In addition it must organize the work of human talent to achieve significant work in the field of implementation of the ICT educational processes (Eraso, Walls, & Insuasty, 2009).

Also, it is observed that the Regional Conference on Education United Nations Organization for Educational, Scientific and Cultural, cited by Torres Velandia, Garcia Ponce de Leon & Barona Ríos (2009), states that "one of the aspects linked to the recommendations to enhance the opportunities offered by ICT, demands that commitments must be taken from the governments and the higher education institutions to ensure the appropriate training of all the people, who make possible the efficient functioning of the services they provide by the telecommunication and-information systems" (p. 109).

Clearly, it is necessary as a result of the introduction of technological infrastructure at the university, hiring or promoting people to positions or jobs newly created, with different and innovative profiles (Duart & Lupiáñez, 2005). As it can be seen, for these authors, the working staff play an important role in educational institutions, because from their different perspectives. We must stress that it is necessary to train the people who make the university organizations up to obtain the expected results during the process and development of the action to be executed, taking into account the needs of each institution. This factor considers the following sub-factors: information technology management (technical support) and users (teaching literacy).

a) Information technologies management (technical support). This is an important factor. Teachers need technical assistance to operate and maintain the technology so they can feel safe when using them in their classes. The lack of adequate infrastructure, technical support and technology competition may baulk the access and user confidence, causing the lost of opportunities for learning and increasing frustration on teachers. Therefore, it is recommended to make available additional support or technical training, depending on local circumstances (UNESCO, 2004, p. 82). On the other hand, it is important to consider that an institutional support for educational innovation consisting of giving technical assistance in situ and continuous training, it is valuable to teachers (Badia, A., Meneses, J. & Sigalés, C.,2013). Given the importance of ensuring the appropriate and relevant tools and technologies to respond to the teaching virtual learning processes it must be assumed the technological dimension as the fundamental pillar for the HEI. The institution must provide timely the intellectual, technical and technological capital needed for all processes required in a virtual learning environment. Also, this dimension should provide a operational system of technical sustain, which meets the requirements in the use of ICT, to support the work of teachers, tutors, facilitators and researchers (Universitaria Virtual Internacional, 2013, p. 52).

Thus, Salinas, J. (2004) proposes to "implement a policy of technical support which is a team that will carry out the project, they must be content experts, who are in charge of instructional design, digital design, etc." To introduce ICT in HEIs, it should be considered among other things, a system of user support to help them solve problems that arise; it should has a worker staff with expertise and available infrastructure needed for the use of technology in academia (Moreno & Mariano, 2002; UNESCO, 2004).

b) *User (teaching literacy).* Salinas, J. (2004) indicates that one of the important aspects to consider when implementing an ICT project is the support system for teachers, who must integrate the actions of the training and retraining plan for teachers regarding the use of ICT in teaching, as well as a system of personal counseling and technical assistance that allows to updated training services of the institution, available resources, technical support, among others.

The proposed incorporation of ICT at the Universidad de Nariño, indicates that when trying to develop skills related to the use of tools for both teachers, students and administrative staff, a permanent training plan must be generated for the responsible units and with the implementation of technical monitoring of the students (Eraso et al 2009). Salinas J. (2000) also states that the introduction of new technologies in universities should be considered a privileged means to achieve the changes brought about the technological evolution. So it is necessary to have skilled and continuously trained workforce, mainly related to these changes. As Almerich, Orellana, Suárez-Rodríguez and Díaz-García (2016) say that ICT literacy teachers must focus on two important areas: technological skills and teaching skills, and this is influenced by personal and contextual factor.

For its part, Duart & Lupiáñez (2005) point to the need of teachers technology training from different types of innovation and use of existing ICT in the processes of educational innovation. This view is complemented by the proposal of giving incentives in different ways (stock, structures, materials, etc.) aimed to promoting the implementation of the technology curriculum by teachers. This stimulus can be the establishment of permanent support and technical and didactic advice (Salinas, M. I., 2010).

Likewise, Heitink et al (2016) has found that the use of technology by teachers shows aspects of the knowledge transfers model of teaching, which means that the use of ICT is intended to support learning activity and strengthen the pedagogy..

According to a study, conducted at the Universidad Autónoma del Estado de Morelos (UAEM), the human resources who work actively in supporting technological infrastructure and in the operation of the telecommunication networks, are rated as specialized and non-specialized personnel; in this regard, there are some full-time professors who say this is insufficient (Torres Velandia et al, 2009).

On the other hand, it is observed that, as noted by Fernández Batanero and Torres Gonzalez (2015), one of the factors that can influence the transformation of teaching performance in the use of ICT in educational practice, is the technological level of teacher training. As Celaya Ramírez, Lozano Martínez, & Ramírez Montoya (2010) says the selection and adoption of a particular resource in its class it is determined by the knowledge and experience that the teacher has in his specialty area as well as the domain in teaching strategies.

Therefore, in the HEIs it is important to find alternatives that lead good literacy teachers to ensure comprehensive training in different areas to perform, depending on the function to be met by each one.

Infrastructure factor

This factor includes both physical and technological infrastructure, as well as human support, financing, the relationship between technological infrastructure and academic planning, and the roles of the authorities in incorporating ICT projects. For technology-based education, an appropriate technological infrastructure is a fundamental requirement (Bates, 2001). The same author, Bates (2001), describes the elements to consider in this factor, including adequate technical support personnel for faculty members, as well as networks, hardware and software. Salinas J. (2004), states that the incorporation of ICT in training, under the concept of flexible learning, generates changes, related to the technological infrastructure, the content and materials, and the access and use of digital resources.

In several studies, it is suggested that in the introduction of ICT in universities it is important to consider the technological infrastructure, which is essential to ensure that learning opportunities are provided (Moreno & Mariano 2002; Torres Velandia, Garcia Ponce de León, Barona & Rivers, 2009). Priority should be given to the needs of expansion and modernization of equipment and technology infrastructure, as ICT become the transversal axis that articulates and consolidates information systems, education and research (Torres Velandia et al, 2009). In this regard, there are conducted studies that support the importance for the institutions having infrastructure to carry out relevant and effective learning experiences (Sancho Gil, 2011). This is corroborated by Garzón Clemente (2015) which states that proposals on infrastructure should include conditions such as open and closed environments for agency collaboration, physical and logical networks, and common standards for telecommunications, among others.

From the above it can be deduced that teachers have a continuous improvement of their skills related to ICT in their application, if they have at their disposal the technological infrastructure and appropriate technical assistance. This is why the UNESCO (2004) states that all students and teachers should have access to new technologies, software, and telecommunications networks, both inside and outside the classroom. It is noted that the ICT infrastructure measures the perceived of the ICT tools availability and suitability, such as hardware, software and peripheral equipment provided. It also refers to the availability of equipment, software, Internet access and other similar resources (Lu, C. Tsai, C.-C., & Wu, D., 2015).

The technological infrastructure not only refers to equipment and tools themselves, but, as mentioned above, it is necessary to have a number of applications, platforms, software, database with specialized tools, networks, among others. Derived from this, the sub-factors related to the infrastructure factor are: hardware, software and networks.

a) *Hardware, software and networks.* The authors considered agree that these three sub-factors are equally important, and are closely related, that is why they will be discussed together.

For Bates (2001), the field of technology infrastructure includes the subcomponents of software and web resources, noting that one of its components are digital resources, which are directly related to the connectivity. Also, Marqués Graells (2000) remarks that the technological infrastructure basically comprises the provision of multipurpose study halls and computer rooms connected to the Internet, for the needs of teachers and for the students free use, and the creation a videoconferencing room and a "virtual campus".

For its part, Duart & Lupiañez (2005) state that "accessibility, connectivity and portability technology for students, faculty and staff management are emerging today as a new scenario of the introduction of technologies in most universities" (p. 13). To do this, it should be keep in mind the points made by the Regional Conference on Education UNESCO 2008, that says that one of the aspects relating to the recommendations to make real the ICTs opportunities, is to ensure the construction of communication networks (Torres Velandia et al, 2009).

Web 2.0 is known as "a social phenomenon in relation to the creation and distribution of content on the Internet, characterized by open communication, decentralization of authority, freedom to share and use within an approach that treats relations human as a conversations" (Ortiz de Zarate, 2008). It is observed that the Web 2.0 or social Web has allowed a collaborative and social approach to educational training, and the absolute possibility of content creation; likewise, the Web 3.0 or Semantic Web, allows to describe content, meaning and value of the data (disruptive technology), incorporating "intelligent agents" (Sandia Saldivia, 2015). Then, for some authors as Peña Ochoa & Peña Ochoa (2007), the Web 2.0 is the tool in the education, since it offers a rich and diverse process of encounters and experiences. It is noted that the HEIs today are supported mostly by dozens of e-learning technologies. This indicates that technology has played and continues to play an important role in the development and expansion of online education (Boa Reena Tok & Marpe Sora, 2013).

On the other hand, network technologies have disruptive effects generated in all organizations, forcing them to drastically restructure their processes and products, resulting in unimaginable social and economic innovations. The network is a profoundly disruptive technology, which requires changes (Anderson, T., & McGreal, R., 2012). Moreover, as Betancourt Franco, M.C., Celaya Ramírez, R. & Ramírez Montoya, M.S. (2014) point out that networks ensure strategies and connective actions important to develop new knowledge. HEIs are not immune to these changes. For these reasons, among others, it is important to promote incentives in different ways to point out to the actual implementation of the technology curriculum by teachers. One of these stimuli may be a subsidy scheme for users to purchase hardware, software, and computer equipment and have free internet access on campus (Rogers & Shoemarker, 1974).

Briefing, Salinas, J. (2004) coincides with previous authors, pointing out that "undoubtedly, little you can do in the field of ICT-based teaching without clear strategic guidelines concerning infrastructure" (p. 11). For him, a technological plan of the institution will be a good foundation for success. However, he remembered that innovation is a human, not a technical activity.

It could be concluded that for a successful development of the academic process supported by ICT, there must be a technological complement with free structural availability, allowing teachers to access the material available to them for the methodological development of their educational program, and thus teach properly to the students, who should also have access anytime, anywhere, to execute a consonant process of learning.

Strategic management factor.

Related to this factor, there are a number of studies that defend the importance of strategic management on the implementation of programs ICT based in universities. For example, Duart & Lupiáñez (2005, p. 13) indicate the urgent need for strategic planning and the creation of a policy of alliances for outsourcing management processes and infrastructure maintenance. These authors suggest that "the initial lack of strategic planning decisions on technology infrastructure has led, in some cases, on erratic procurement policy, on the added difficulty in the realization of the processes of technology management, in difficulties not provided on the maintenance and improvement of the equipment and its renewal".

In addition, the proposed incorporation of ICT at the Universidad de Nariño, noted that developments in technology must be designed under professional engineering parameters and obviously all these processes should be articulated with the criteria of strategic planning and should be controlled or regulated (Eraso et al, 2009). Likewise, Mariano & Moreno (2002), point to bear in mind some aspects, which should be a system of user support to help them solve the problems that arise when they are implementing ICT in educational processes.

This factor, as well as everything related to the strategic plan for technology integration, and the teachers' support actions should be evaluated periodically, aiming to establish the degree of efficiency in terms of the planned. This evaluation will define institutional policies and incorporate any improvements that may be necessary (UNESCO, 2004).

All this points to find the adequate guidelines for good performance and operation of the processes required according to every need. In this factor questions and analysis are made to verify and confirm that everything has been properly exploited, providing quality service. Technological prevention and technological improvement are two sub-factors presented on the strategic management factor.

a) Technological prevention. The main objective of the technological dimension must be to ensure the operating conditions of the technology management system components. This involves, among other things, the adequacy of physical space and electrical networks, network installations, computer systems, as well as maintenance of the technological infrastructure and software licensing. It cannot be left out that it should promote ethical, safe and efficient use of technological infrastructure (Universitaria Virtual Internacional, 2013).

In the same vein, all the above "framed in a safe and reliable technical and technological environment to ensure and maintain the integrity, confidentiality, availability, storage, stability, privacy of information; that develop contingency plans, electronic backup systems, monitoring and authenticity of the information and data" (Universitaria Virtual Internacional, 2013, p. 53). In this context, Scott Daniels, J. Jacobsen, M., Varnhagen, S. & Friesen, S. (2013) note that the access is a limiting issue in the effective use of technology factor. This makes that the selection and access to high-quality learning resources for students, can directly affect pedagogy, and therefore decisions about the resources to be used.

From the above it is concluded that it is necessary in HEIs to have electronic backup systems and contingency plans, where they regulate and preview the possible mistakes related to the use of technologies that may arise in the development of programs supported by ICT, in order to provide quick, safe and effective solutions.

b) Technological improvement. This sub-factor is related to the need to constantly evaluate the effectiveness of technology in all instances of teacher training. This will reveal the institutional vision about whether if using technology is going in the right direction. But mostly it will identify the potential problems to change institutional policies and strategies (UNESCO, 2004).

Likewise, for the success in the project, Salinas, J. (2000) says that it is necessary to have "content quality (any service will not have educational value if the materials it contains are not quality; it is obvious that what will prevail will be the contents over the multimedia artifice fires)" (p .18). Moreover, Sahasrabudhe, V y Kanungo, S (2014) has found that the relationship between media choice and its effectiveness is moderated by the learning domain and the learning styles of learners. This means that a big part of the quality of the program would be based on the media selection.

Clearly, if the HEIs want to provide good services need to provide quality programs, not only in the technological infrastructure, but services provided in general. It is important, therefore, to implement periodic evaluations to diagnose the efficient functioning and identify the required improvements.

The following table shows each one of the factors and sub-factors found to be influential in the process of adoption of ICT, and the authors who points them in their publications.

Table 1. Factors and Sub-factors With the respective authors.

Factor	Authors alluding the factor	Sub-factor	Authors alluding the sub-factor
Personnel	Sancho Gil, 2011. Torres Velándia, García Ponce de León, & Barona Ríos, 2009. Duart & Lupiáñez, 2005. Eraso, Paredes, & Insuasty, 2009. Bates, T., 2001. Celaya Ramírez, Lozano Martínez, & Ramírez Montoya, 2010.	IT management (technical support)	Salinas J. , 2004. Universitaria Virtual Internacional, 2013. Moreno & Mariano, 2002. UNESCO, 2004. Badia, A., Meneses, J. & Sigalés, C.,2013
		User (teaching literacy)	Torres Velándia, García Ponce de León, & Barona Ríos, 2009. Salinas, J., 2004. Salinas, M. I., 2010. Duart & Lupiáñez, 2005. Eraso, Paredes, & Insuasty, 2009. Salinas, J., 2000. Sahasrabudhe, V y Kanungo, S (2014). Heitink et al, 2016. Almerich, Orellana, Suárez-Rodríguez and Díaz-García (2016)
Infrastructure	Sancho Gil, 2011. Torres Velándia, García Ponce de León, & Barona Ríos, 2009. Bates, T., 2001. Salinas, J., 2004. Moreno & Mariano, 2002. Salinas, J., 1997. Duart & Lupiáñez, 2005. UNESCO, 2004. Boa Reena Tok & Marpe Sora, 2013. Lu, C., Tsai, C.-C., & Wu, D., 2015. Anderson, T., & McGreal, R., 2012. Garzón Clemente, 2015.	Hardware	Salinas, J., 2004. Rogers & Shoemarker, 1974. Marqués Graells, 2000. Bates, T., 2001.
		Software	Salinas, J., 2004. Rogers & Shoemarker, 1974. Marqués Graells, 2000. Bates, T., 2001
		Networks	Salinas, J., 2004. Rogers & Shoemarker, 1974. Bates, T, 2001. Peña Ochoa & Peña Ochoa, 2007. Torres Velándia, García Ponce de León, & Barona Ríos, 2009. Duart & Lupiáñez, 2005. . Betancourt Franco, M.C., Celaya Ramírez, R. & Ramírez Montoya, M.S., 2014
Strategic management	Moreno & Mariano, 2002. UNESCO, 2004. Duart & Lupiáñez, 2005. Eraso, Paredes, & Insuasty, 2009.	Technological prevention	Universitaria Virtual Internacional, 2013. Scott Daniels, J., Jacobsen, M., Varnhagen, S. & Friesen, S., 2013.
		Technological improvement	UNESCO, 2004. Salinas, J., 2000.

Source: Self prepared, based on the authors.

CONCLUSIONS

In the research process, object of this work, a theoretical-conceptual review of the main factors influencing the adoption of ICT in universities, regarding the organizational, technological and teaching-learning dimensions, present in the different models studied and specifically in the MEN proposal, and from the analysis of the criteria raised by them, focusing on technological infrastructure dimension, was made. The information obtained was classified and organized by a theoretical mesh, in which the different elements that each of the authors found were reflected, as necessary, to model the adoption of ICT. This allowed, at the end of the process, to unify and establish the factors and sub-factors that were defined as the research product

It is important to consider a technological infrastructure that include conditions such as open and closed environments for agency collaboration, physical and logical networks, and common standards for telecommunications.

The major factors found are: personnel, infrastructure and strategic management. In turn, each factor derived a number of sub-factors, namely: the personnel factor, which implies IT management (technical support) and user (teaching literacy); the second factor is the infrastructure, in which there are presented the sub-factors hardware, software and networks; for the third and final factor, the sub-factors are technological prevention and technological improvement.

Among the most significant aspects pointed by the authors, there is the importance of having qualified personnel, capable of performing the tasks associated with each academic program, and in turn they should have access to technological equipment for developing, effectively and efficiently, the process of adoption of ICT in the HEI. In Addition, it must have strategic plans that help to improve, solve and fix troubleshoot and problems that may be faced in carrying out this process. To do this, it is suggested to make periodically an evaluative analysis of all mentioned above, it should determine the progress in order to provide high quality services.

From the related factors found, one of the aspects most mentioned by authors is the technological infrastructure, indicating the relevance of that in teaching based on technology; the appropriate technological infrastructure is a key requirement. Perhaps, because when talking about e-learning, a key supporting factor is the technological platform in which the programs lie. It is essential to carry out the teaching and learning processes, as well as to innovate and optimize methodologies taught by universities today. Related to the previous factor, there is the sub-factor networks, where most of the authors noted that accessibility and portability of technology is necessary in terms of bandwidth, network services and web sites for both, academic and administrative staff, anytime, anywhere.

Also, almost all authors have suggested that the sub-factor user, specifically with regard to teaching literacy is vital for the success of the process of adoption of ICT. They indicate that teachers must have related skills with the knowledge, selection and use of technology to be reliable to use it as a tool for teaching innovation. In addition, teachers must understand the challenges of the knowledge society, and act accordingly. For teachers it is necessary to consider that an institutional support for educational innovation consisting of giving technical assistance in situ and continuous training. In conclusion, practically all the authors indicated that for the e-learning process is essential to train teachers in all matters relating to the use and knowledge of new technologies; and the need to motivate and create incentives on the HEI, that will provide new opportunities for teachers. Likewise, to ensure that HEI provide good services and quality programs, it is important to implement periodic evaluations to diagnose the efficient functioning and identify the required improvements.

The consolidation of the factors involved in the appropriation of ICT from a technological perspective, as a result of this study, concludes that it is of great interest and valuable importance to analyze the different variables that influence this appropriation, to ensure that they work as generating educational innovations in teaching practice. In this sense, the document presents to the HEI valuable elements that can ensure better results when starting ICT adoption processes. Also note, that these results can serve as inputs to define institutional policies aimed at the training of teachers and the appropriation of ICT at universities.

Complementing this work it is significant doing like studies to gain a better understanding of the other two dimensions proposed by the MEN methodology, which are pedagogical and organizational dimension, in order to reach a full understanding of the adoption of ICT process in the HEI.

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Received 7-05-2016 /Approved 15-05-2017

Analysis of scientific content on labels and their educational implications: the case of clothing

Análisis del contenido científico de las etiquetas y sus implicaciones educativas: el caso de la ropa

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Abstract

This paper presents the results of the analysis of scientific content on labels of dress clothes. The study is focused on classifying information, determining the cognitive demands involved and evaluating the basic knowledge to which citizens of any country have to face in a daily process: the choice of clothes. The results indicate that there are many scientific-technical concepts around clothing, which seem to demand an increasingly specific training. Finally, we discuss the implications of these results for citizens' education as well as in its possible use as a reference for formal education.

Key words: *science literacy, science in everyday life, buying process, citizens' education, labeling.*

Resumen

En este trabajo se presentan los resultados del análisis del contenido científico de las etiquetas de prendas de vestir. El estudio se centra en la clasificación de la información, la determinación de las demandas cognitivas involucradas y la evaluación de los conocimientos básicos a los que los ciudadanos de cualquier país tienen que enfrentarse en un proceso cotidiano: la elección de la ropa. Los resultados indican que hay muchos conceptos científico-técnicos alrededor de la ropa, que parecen exigir un entrenamiento cada vez más específico. Finalmente, discutimos las implicaciones de estos resultados para la educación de los ciudadanos, así como en su posible uso como referencia para la educación formal.

Palabras clave: *alfabetización científica, ciencia en la vida cotidiana, proceso de compra, educación ciudadana, etiquetado.*

INTRODUCTION

Obtaining resources is a basic need for all living beings. This fact is so transcendent that, at times, human societies have been named in terms of how they acquired and managed these resources. We thus speak of societies as being hunter-gatherers, hunting, agricultural, bartering, and commercial…In our world people fundamentally acquire goods through the buying process. This daily task has turned into one of the structural characteristics of our way of life and culture (McCracken, 1989), and has reached such importance that we now speak about living in a consumer society. This phenomenon has been studied by diverse social sciences such as economics, sociology, history, psychology, anthropology, etc., and has given rise to new professional fields such as marketing and advertising.

The societal environment in which we live is now based upon science and technology as well. Our society is shaped by technological innovation to such an extent that the characteristics of our culture and its evolution could not be understood separately from the scientific-technological advances which systematically modify our world (Korotayev, Malkov, Khaltourina, 2006).

These factors –consumption on the one hand, and the presence of science and technology on the other– have been considered through a social prism. According to the results of surveys carried out by the FECYT (Fundación Española para la Ciencia y la Tecnología = Spanish Foundation for Science and Technology) on the social perception of science and technology, spontaneous interest in science and technology has significantly increased in the last few years in Spain (FECYT, 2015). Despite this favorable evalution, however, the survey also shows that almost half of the general population (47.1%) believes their science education levels to be low or very low. Be that as it may, this clearly demonstrates the need for ~~the~~ institutions to analyze how the general population perceives scientific subject matter~~s~~ and the value they assign to them.

This situation - interest in Science and Technology and the perception of little training - leads to the suggestion that there exists a need for what has been defined in didactical terms as scientific literacy. As has been indicated in various studies although expressed differently, this requirement originates in the science and technology present in everyday life (Linn, 2002). In other words, it seems that the interest and value that the general population grants to these issues is to a certain degree linked to their relevance to the tasks of everyday life (health, nutrition, consumption, the environment…).

The analysis of the relevant daily life situations presenting scientific-technological content shows that there is a multitude of such circumstances (Ezquerra y Fernández-Sánchez, 2014). Science can be found in advertising (Campanario, Moya y Otero, 2001; Pitrelli, Manzoli y Montolli, 2006; Belova, Chang y Eilks, 2015); in certain TV programs (Dhingra, 2003; Ezquerra y Polo, 2010); in some high impact news stories (Oliveras, Márquez, y Sanmartí, 2013; Halkia y Mantzouridis, 2005; Jiménez-Liso, Hernández, Lapetina, 2010); in the information provided by weather reports (Ezquerra y Pro, 2006); and in the science sections of the press (Halkia y Mantzouridis 2005; Jarman y McClune, 2007) amongst others. All of this scientific-technological content is put forth in mass media communication in informative, educational, advertising and entertainment areas. The presence of this content in the media and the way in which it is presented determines part of the general population's social perception of it (O'Sullivan, Dutton y Rayner, 1998).

Equally worthy of consideration however, is the content which is embedded in other sources such as social debate (Ezquerra, Fernandez-Sanchez y Magaña, 2015; Hadzigeorgiou, 2014); or all of the scientific and technological questions related to concerns such as medicine, health, the environment, and the buying process(Sørensen, Clement y Gabrielsen, 2012), amongst others.

All of these factors with scientific-technological content are of crucial importance to the world in which we live and form part of the elements which make up what a person should know about Science in order to understand his/her environment. In Experimental Science Didactics terminology, we would say that these are reference points for correct scientific literacy. In other words, to be capable of making decisions related to personal welfare, social welfare and environmental welfare (Harlen, 2001; Lemke, 2006). This implies the ability to single-handedly respond to the numerous situations which come up in a person's day to day life (Hogan, 2002; Kolstø, 2006; Lewis y Leach, 2006).

This aspiration is reflected in a great number of educational policy reports by organizations such as UNESCO (1994), International Council for Science (UNESCO-ICSU, 1999), and the Latin American States Organization for Education, Science and Culture (OEI, 2001), as well as in the positions of prestigious and influential professional associations which have fostered highly ambitious scientific and technological projects, such as the American Association for the Advancement of Science (AAAS, 1993), the International Technology Education Association (ITEA, 2000), or the National Research Council (NRC, 1996), amongst others.

The appropriate analysis of these issues however, is beyond the scope of just academic training (Cajas, 2001; Desautels y Larochetelle, 2003) and requires expanding research out of educational centers.

OBJECTIVES

In this context, it is of great interest to determine what people need to know, from a scientific point of view, in their day to day lives. Given the vast scope of this knowledge, this study has focused upon a specific context: the buying process and more specifically that involving clothing. The purpose of this analysis is to determine the scientific content present in the labeling of clothing and the way in which it can be categorized in terms of didactical concepts. The study centers on classifying information, determining the implied cognitive demands and assessing the basic knowledge people need to face in a process as mundane as choosing clothing.

In this manner, and from the viewpoint of scientific literacy, we intend to establish certain reference points to indicate the type of content faced by people all over the world. We believe that, in spite of significant proposals (p.ej. Membiela, 2002; Marco-Stiefel, Ibáñez y Albero, 2000), to date there are no clear reference points indicating what a person needs to know to be considered as scientifically literate.

Furthermore, and from a perspective closer to formal education, one of the main problems in the teaching of the sciences is the disconnect between the themes taught in class and the day to day reality of the students (Pozo y Gómez Crespo, 1998; Duggan y Gott, 2002). As such, we intend to examine how this content can be incorporated into the classroom.

We must also remember that the concern with regards to this content is not exclusive to the academic world. There are organizations such as the European Union which gather in its norms (EC/96/74) directives governing the information present in the labeling of textile products. Equally, we can find analogous examples in the legislations of all countries and in most cases, these legislative texts appear to suggest that citizens must not only be able to understand the information about the product but also participate in the management and supervision of consumer information. However, the achievement of this goal is impossible without knowing the effects of this content on the general population.

METHODOLOGY

Once the object of the study had been decided – clothing - the next step was to establish where to collect the data. Various sales outlets were analyzed in order to produce a list of the different commercial formats to be found internationally: department stores, specialized shops (work clothing, sports clothing, furriers…), fashion stores (boutiques, shopping malls), online stores and small traditional businesses.

Each type of establishment offers its own communication focal point. Hypermarkets provide a wide range of choice and allow customers to explore thousands of possibilities but typically have a sales force which is relatively untrained in the products they sell. Specialized stores and traditional businesses however, offer the possibility of personalized assistance. This is an important difference as the first step in the decision making process is identifying, classifying and understanding the significance of the provided information.

The data collection was carried out in different businesses in an attempt to cover all of the commercial possibilities and the range of existing products; furthermore, criteria of proximity and economy of effort were also taken into account. This represented more than 200 stores and close to a thousand different types of clothing. In truth, it is difficult to provide an exact figure as the last phases of research consisted more in screening and contrasting data to determine what was lacking rather than in accumulating more articles that had already been considered.

The clothing was subsequently grouped into five large categories in order to achieve a first classification (Table 1). This first classification was carried out so as to share out field work amongst the researchers and to do so reasons of functionality of the clothing were utilized. This division however, turned out to be more transcendent for the interests of the study than had been originally anticipated. The fact is that dress clothing is more often than not considered from a fundamentally esthetic viewpoint by both buyers and sellers which in turn leads to scant scientific-technical information. On the other hand the situation is different when it comes to sports or work clothing as it seems that their utilitarian nature requires a more detailed explanation of their characteristics.

The next step, carried out simultaneously, consisted in extracting the emergent information units in the labeling and classifying them in terms of their links to scientific and technical content. This permitted the establishment of the following categories: a) information referring to physical magnitudes and units: b) information referring to product composition: c) information referring to handling (washing, drying, ironing and dry cleaning); d) information referring to specific terminology. It was also possible to confirm that, in accordance with EC Directive/96/74 concerning textile denominations, all labels follow a similar model. It is also true that certain articles, such as sports and specialized clothing, offered extra information. This additional data was also taken into consideration and classified even though it did not appear in the mandatory labels.

Table 1. Classification of clothing

Category	Clothing
Clothing: casual, fashion…	Sweatshirts, shirts, sweatshirts, blouses, sweaters, trousers, skirts, leggings, dresses, undergarments, handkerchiefs, tops, belts, shoes, sports shoes, etc.
Sports clothing	Cycling (jerseys, cycling shorts, helmets…); athletics and running (caps, t-shirts, tights, running shoes…); mountain sports and skiing (coats, wind breakers, fleeces, boots, trekking footwear…); swimming and diving (bathing suits, bikinis, wet suits, caps...); etc.
Winter clothing	Jackets, coats, heavy jackets, umbrellas, raincoats, etc.
Work clothing	Coveralls, reflective vests, protective helmets, metallic protective clothing, anti-static clothing, Firemens' (fireproof jackets and pants); police (bulletproof vests, punctureproof gloves); military (cammies); protective footwear, etc.
Smart clothing	Clothing with biomedical sensors, corrective clothing and soles, anti-cellulite pants…

RESULTS AND DISCUSSION

The objective of this work is not to enumerate in detail all of the information units of a scientific nature which appear in labels but rather to reflect upon the knowledge necessary to apprehend this content. This is why the tables in this work only bring together some of these information units and more concretely those which appear most frequently.

Physical magnitudes and units

The main purpose of the *physical magnitudes and units* is to characterize the product using objective information. Contrary to what happens with food products, appliances and electronic devices (Ezquerra y Magaña, 2016), the content related to physical magnitudes which appears in the labeling of clothing and footwear is quite scarce. Within this group, we have identified two types of magnitudes: pre-established physical magnitudes and those of convenience. The pre-established physical magnitudes describe properties both universal and specific to the article in question using units previously established. On the other hand, the *magnitudes of convenience* are those which have been created to measure a concrete property of the product by way of a unit created *ad hoc*. In this study, this type of magnitudes appears especially in the labeling of sports and work clothing given that they present highly specialized properties. In Table 2 you can find examples of both pre-established magnitudes and magnitudes of convenience.

Upon examination of Table 2, we can say that the *pre-established physical magnitudes* are stable, homogenous and tend to use units of the International System. Within the *physical magnitudes of convenience* however, we find a maelstrom of units, some adimensional and frequently coming from the English speaking world. They present heterogeneous information, at times highly debatable, where there are no pre-established standards as to what to measure and which units to use. With some of these measurements, the consumer is unable to contrast brands or models and can be at the mercy of the makers' fancy. Nevertheless these magnitudes and units can at times present information of great interest to the consumer. For example, the Spray Test is used to measure the waterproofness of a fabric in which 80/20 means that 80% of the material repels water after 20 washing cycles. In any case, these magnitudes of convenience seem to originate in the desire to familiarize the end user with the properties of the product. In other words, these magnitudes appear as a need for communication with the customer.

As for size—surely the magnitude we focus on primarily when buying--, this will vary depending on gender, country, maker and also the type of clothing. Nonetheless, in general, this magnitude is usually shown in an adimensional fashion using numerical systems (36, 38, 40…) or alphabetic (S, M, L, XL…). Obviously these correspond to units of the International System. For example, a woman's size 40 will indicate that a person has a bust size of approximately 91 cm, 71 cm waist and 99cm in the hips even though we must point out that nowadays women's sizes are a matter of great controversy. We would also add that this is the case in continental Europe whereas these dimensions would be a size 12 in the United Kingdom, a size 8 in the United States, 42 in Brazil or an 11 in Japan.

Table 2. Physical magnitudes and units present in clothing

<table>
<tr><th>Category</th><th>Magnitudes</th><th>Units</th><th>Clothing</th></tr>
<tr><td rowspan="3">Pre-established physical magnitudes</td><td>Washing and ironing Tª</td><td>ºC, ºF</td><td>All but footwear</td></tr>
<tr><td>Dimensions</td><td>cm, " (Inches)</td><td>Sports clothing</td></tr>
<tr><td>Mass</td><td>kg, g</td><td>Sports clothing and footwear</td></tr>
<tr><td rowspan="10">Physical magnitudes of convenience</td><td>Impermeability</td><td>PSI (Pounds-force per square inch)</td><td>Sports clothing and work uniforms</td></tr>
<tr><td rowspan="3">size</td><td>S, M, L, XL…</td><td rowspan="2">All but footwear</td></tr>
<tr><td>36, 38, 40, 42…</td></tr>
<tr><td>37, 38, 39, 40, 41…</td><td>Footwear</td></tr>
<tr><td>Breathability or RET (Resistant to evaporation transfer)</td><td>g/m2 in 24h</td><td>Sports clothing, work uniforms and footwear</td></tr>
<tr><td>External fabric's resistance to water</td><td>Adimensional fraction</td><td>Sports clothing and work uniforms</td></tr>
<tr><td>Wind resistance</td><td>CFM (Cubic feet per minute per squared feet)</td><td>Sports clothing and work uniforms</td></tr>
<tr><td>Quality of feather filling</td><td>Cu ins (Cubic inches)</td><td>Sports clothing</td></tr>
<tr><td>Percentage of filling</td><td>adimensional fraction</td><td>Sports clothing</td></tr>
</table>

Composition

The composition of the different types of clothing and footwear vary extensively which has led to an ample and heterogeneous list of materials. We therefore opted for a classification in terms of origin (Table 3) be they natural (animal, plant or mineral) or synthetic (polymers). It must be pointed out that despite being of natural origin all the materials comprising the fabrics used in clothing have been processed. These different types of treatment however, either chemical or physical, are usually not taken into account. Elements such as thread size, number of fibers per surface unit, type of dye, etc., are usually omitted as well. All of these aspects speak of the characteristics of the product being bought and often are a mark of the quality of the fabric. These characteristics only came up in some of our conversations with shop assistants in traditional businesses.

Table 3. Composition of clothing

Origin		Materials
Natural	Animal	Wool, fur (mohair, cashmere…), skin-leather (bovine, ovine…), feather-down and silk.
	Plant	Cotton, hemp, linen, esparto, paper, raffia…
	Mineral	Fiberglass, asbestos (highly regulated use),
Synthetic (polymers)		Carbon fibers (P140), polystyrene, polyamide (nylon), polycarbonates (PC), polyurethane, polypropylene, neoprene, polytetrafluorethylene, PVC, rayón (viscose, acetate, cupro, polynosic), acrílic fiber, silicone, gortex, dyntex y aramids (meta and para), elasthene (spandex, lycra) y elastomultiéster.

In Table 3 we can observe that there is a great variety of types of synthetic materials as opposed to natural ones. Polymers, materials which revolutionized the textile industry in the first third of the twentieth century, used either individually or in combination, are present in the vast majority of fabrics used in clothing today.

This option of combining substances has allowed for an infinite number of possibilities in terms of proportions, composition and weave. It has generated a universe of options each with its own characteristics and properties. Furthermore, many of these polymers are named differently by different makers making it difficult for the consumer to discern which is which. In any case, the consumer is faced with cognitive demands coming from different fronts be they identifying the type of materials, recognizing their characteristics or properties, and having a handle on the proportions or percentages of composition.

Processes

The analysis of the labeling of clothing and footwear demonstrates the existence of a great amount of information referring to processes. These are of two types: how was the fabric made and how it must be maintained. The first, the making of the fabric, does not require any action from the customer but rather is linked to an understanding of the quality and properties of the article of clothing. The second element of this classification however, the maintenance of the article in question, does make a procedural demand: the user must take concrete steps. Table 4 is just a sample of the procedural content classified in terms of ironing, washing, drying or dry cleaning.

Table 4. Procedures present in clothing

Subcategory	Process
Ironing	Iron at x ºC (ºF).
	No hot air.
	(no) steam ironing.
Wash	Wash at x ºC.
	Wash at low temperature.
	Wash with reduced moisture.
Dry	Use dryer at x ºC.
	Do not sundry.
	Dry without heat.
Dry-cleaning	(No) Use of mineral essences.
	(No) Use of perchloroethylene.
	(No) chlorine based bleach.
	(No) oxygen based bleach.
	(No) Use of ordinary thinner.

These four procedural categories appear in all of the labels of the analyzed products which underlines the need for the consumer to understand concepts such as temperature (º C, ºF) or the command “Do not use perchlorethylene”; “ iron with (without) steam” or to know which chemical products to use in dry-cleaning the product. Moreover, the symbols used in labeling to identify these procedures can be too technical for most consumers.

Specific terminology

Specific terminology is essentially found in the labeling of specialized clothing (sports, work and smart clothing). The content found (Table 5) was interesting and gives an idea of the huge diversity of circumstances in which science and technology appear in people’s lives. Furthermore, much of this terminology is eye-catching and could stimulate students’ interest and as such would be a magnificent starting point or connection between the classroom and certain appealing work environments.

Table 5. Specific terminology presents in clothing

Specífic terminology	Clothing
Infrared treatment.	Military uniforms
Antimicrobe and antibacterian treatment of silver nanoparticles.	Military caps
Reflective material made of retro-reflective wide angle lenses.	Reflective vests
May contain ceramic layers and light steel for increased protection.	Bulletproof vests
Anti-mist and anti-ultraviolet ray treatment of visor.	Cycling helmets
Combines caffeine, retinol, vitamin E, aloe vera and fatty acids incrusted or encapsulated in fibers.	Anticellulíte pants
anti-static threads	Anti electricity t-shirts and boots

IMPLICATIONS

The analysis of the information appearing in the labeling of clothing allows the confirmation that there is scientific content which can be classified into four categories: *physical magnitudes and units (pre-established and of convenience), composition, processes and specific terminology*. Each one of these categories requires a specific didactical outlook within formal education – in the classroom – and a separate level of action/intervention in the general population.

Didactical implications

From a didactical viewpoint and in a synthetic fashion, the pre-established *physical magnitudes and units* are stable and homogeneous which facilitates their selection and academic use in the classroom. On the other hand the *magnitudes of convenience,* which are more creative, allow us to introduce an element of educational interest not often seen in the classroom, namely creativity. They would also make it easier to give students real examples of how units are developed, estimations are done and how analogies are sought amongst measurements. These facts offer an excellent opportunity to carry out verification tests and promote the measurement of elements of daily life for students.

In relation to *composition,* activities connected to polymers and the proportions in which they are found could be carried out: what are polymers, how are they synthesized, what are their structures, what are they used for, in what percentage, evolution throughout history, etc. The objective would not be to train students to be experts in the textile industry but rather people who understand the difference between different types of fabrics and why some are used and others not in the making of particular articles of clothing.

For its part, the *processes* category brings together the actions which are asked of, or recommended to, the user (ironing, washing, drying, cleaning…). These instructions concentrate conceptual demands (temperature, perchlorethylene…), action protocols (dry-clean with reduced moisture…) and should generate curiosity about why one must take this action and not another. This seems to facilitate minor research projects in the classroom. Finally, within the *specific terminology* category, there are thought stimulating questions which would be a magnificent starting point to connect the classroom with the latest scientific-technological advances.

One interesting fact we were able to ascertain is that scientific and technical contents often appear mixed together whereas in formal training they are broken down into distinct bodies of knowledge: mathematics, physics, chemistry, technology…This is an example of how reality does not establish borders between fields of knowledge whereas this is par for the course in the curriculum of almost every country's educational organization. In our opinion, this fragmentation hinders the students' understanding of the sciences in the way they will perceive them in reality and in the way they will use them in their daily lives. The classroom should offer students the opportunity to appreciate Science in the way it affects their daily lives through the analysis of commonplace products which are so easy to acquire (Gomes, Dionysio, Messeder, 2015).

An interesting proposal for students carrying out minor research projects, either individually or in small groups of 3 to 5 people, would be to start again and gather all relevant information from the labels for later analysis. The following points can be incorporated:

Price and materials used comparison of different articles of clothing.

Correlation between different magnitudes related to sizing: measurement of the article of clothing in cm, proportion between measurements of different parts (back width, inseam, waist circumference…), etc.

Measurement of the impermeability of different fabrics and their degree of resistance to water as hands-on laboratory work.

A reflection upon the role of advertising in consumer habits and decision making when buying clothes. Prompted questions might be; "Why is one article of clothing more expensive than the other when both are made of the same material?" or "What factors come into play when choosing clothing". Critical thought amongst students is thereby encouraged by reflecting upon the role played by advertising in general and the scientific content present in advertisements in particular (Belova and Elks, 2014).

Activities of this type are currently underway and their assessment will be the subject of future work.

These ideas with regards to the classroom are clearly mere suggestions and require consolidation. They need to be tailored to the curriculum of each country, made explicit for each educational level, detailed in planned activities and finally the results of their implementation need to be analyzed. In any case, the reality which surrounds us all – and ultimately our students – must serve as a reference point for the curricula of all countries as we have suggested. These tasks, however, remain pending for future efforts.

Training of the general population

The identification of scientific-technological content and the analysis of training demands stemming from the buying process are not only academic reference points in any educational system but are also elements which give form to the concept of scientific literacy. The Didactics of Experimental Sciences have been promoting these training demands as a way to develop the skills and competencies necessary to a full expression of citizens' rights (Prieto, España y Martín, 2012). Thus, focusing our thoughts upon the general population and using the gathered information as a starting point, it seems that the different contents present in the buying process of clothing generate highly varied cognitive demands.

By way of example, the *magnitudes and units* category require of the individual a conceptual understanding of physical properties and a certain degree of procedural capability to measure and compare whereas *composition* and *specific terminology* seem to contain exclusively conceptual requirements. The category of *processes* demands a specific mode of intervention, a protocol of action by the consumer.

It is also of interest to point out that very few allusions to the environment and sustainable development were found in clothing labels which is somewhat surprising given the common use of materials of animal origin in the making of clothing. Only one case was found alluding to "le pelli impiegate non appartengono inoltre specie di animale protette" [No animal skins of protected species were used]. It is possible that if the labels found in furriers had been analyzed, more information units of this type would have been found. Neither was information on the possible use of recycled materials or the ecological footprint found. However, some examples referring to the non-artificial origin and non-toxicity of substances used were identified but given the limited number of these, it was not possible to group them together into a category. Terms such as "bio cotton", "100% natural wool". "natural dye", "contém partes não têxteis de origem animal", or "tested for harmful substances" were found but these seem to be expressions used for advertising purposes as opposed to reliable information. This information should be demanded by consumers and made mandatory by the competent administrations.

In any case, everyone, and everywhere, is exposed to an incessant deluge of scientific-technological content. This is why, as stated by Rio (1986), education plays—or should play—a decisive role in consumer based societies.

CONCLUSIONS

The aim of this work has been to analyze how Science is present in everyday life, to specify this presence through the collection and classification of scientific-technological content found in a process as mundane as the purchasing of clothing and to consider, as a first step, the cognitive consequences both for the classroom and the general population. Undoubtedly, there is still a long way to go. A multitude of questions arises: what is the complete array of scientific contents to be found in daily life, what cognitive demands do they give rise to, how can we train people to face these demands once formal education has come to an end, what impact does this knowledge have upon the work life and personal life of the individual, how can we analyze these facts, etc. All in all, we consider that the study of how science is present in society, and more particularly the study of the factors which determine this reality, must constitute a line of research from the vantage point of the didactics of the experimental sciences (Pro y Ezquerra, 2005).

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Received 11-05-2016 /Approved 15-05-2017

The Brazilian scientific literacy in the PISA
La alfabetización científica brasileña en el PISA

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Abstract

This study investigated the scientific literacy of Brazilian students through the data of the Programme for International Student Assessment - PISA. Starting from the importance and relevance of discussing the Brazilian scientific literacy it sought to answer to two questions: (a) where are the Brazilian students located in the international context in terms of scientific literacy of PISA?; (b) how do Brazilian students' contextual characteristics, such as their school administrative dependence and socio-economic status, impact their results in Science? For the study, in addition to the determination of descriptive statistics, the analyses were conducted by applying a linear regression model. The results of the 2006 PISA showed that Brazilian students not enrolled at a private school and who do not come from a high-income family have a considerable disadvantage in science. It also showed that the fact of their school being public is alone substantially enough to explain more than 20% of the variance of the average performance in science of Brazilian students and corroborates the results of numerous other studies in educational equality / inequality.

Key words: *international evaluation, scientific literacy, Brazil, PISA*

Resumen

Este estudio investigó la formación científica de los estudiantes brasileños a través de los datos del Programa para la Evaluación Internacional de Alumnos - PISA. Partiendo de la importancia y relevancia de discutir la alfabetización científica brasileña se trató de responder a dos preguntas: (a) cómo son los estudiantes brasileños ubicados en el contexto internacional en cuanto a la formación científica de PISA?; (b) las características contextuales de los estudiantes de Brasil, tales como la dependencia administrativa de su escuela y su estatus socioeconómico, impactan sus resultados en Ciencia? Para el estudio, además de la determinación de la estadística descriptiva, los análisis se llevaron a cabo mediante la aplicación de un modelo de regresión lineal. Los resultados del PISA 2006 mostraron que los estudiantes brasileños que no están inscritos en una escuela privada y que no provienen de una familia de altos ingresos tienen una desventaja considerable en Ciencia. También puso de manifiesto que el facto de ser alumno de la escuela pública es suficiente para explicar en más de 20% la varianza del rendimiento medio en ciencias de los estudiantes brasileños y corrobora el pozo encontrado por otros numerosos estudios en igualdad / desigualdad educacional.

Palabras clave: *evaluación internacional, alfabetización científica, Brasil, PISA*

INTRODUCTION

The Brazilian Association of Science (2008) states that the social, scientific and technological development of Brazil requires a major overhaul of the educational structure in the country. The need to improve basic education in Brazil and, in particular, science education, was a central theme of the document of the Brazilian Academy of Sciences - Science Education and elementary school: proposals for a system in crisis - published in 2008 (ABC, 2008). It is believed that in order to meet the demands of an increasingly complex society, permeated by science and technology, technically specialized knowledge is not enough. Above all, the development of skills to organize thinking, make decisions and deal with data, for example, are crucial to take part in the field of Science. Science and technology define the future of a society and its ability to create and adapt technologies developed from different backgrounds. Even with all the development of science and technology and, although Brazil contributes about 2.7% of the world's scientific production, research conducted in the education field points to a below average performance of Brazilian youth in tests that measure scientific skills and performance in mathematics.

Brazil occupies the 58th place among the most innovative countries in the world.[1]Recognizing science and technology as essential to the economic, cultural and social development of a country, the teaching of Science at all educational levels has growing in importance and has been the subject of numerous teaching transformation movements and can serve as an illustration for implementation and effects of educational reforms. In this paper, PISA - Programme for International Student Assessment - data is used to analyze the results of Brazilian students in Science. The study seeks to understand the school context, assuming that the results of large-scale assessments constitute instruments to understand the school curriculum (Forquin, 1995).

PISA is an international comparative assessment programme, developed and coordinated internationally by the Organization for Economic Cooperation and Development (OECD), applied to a sample of 15-year-old students. The programme takes place every three years, covering three areas of knowledge - reading, math and science - and each edition emphasizes one of these three areas. The assessment seeks to verify the extent to which schools in each participating country are preparing their young people to exercise their role as citizens in contemporary society. It is difficult to imagine a critical citizen who has limited scientific knowledge in a society where scientific knowledge and technological advancement are so important. Although the majority of the population makes use of and gets along with scientific and technological products, individuals do not reflect on the processes involved in the creation, production and distribution of those products. Thus, due to their lack of information they do not make independent decisions and are subordinated to the rules of the market and the media.This prevents the practice of critical and conscious citizenship (BRASIL, 1998). There is a need to prepare young people to be able to participate in some way, in the decisions made in this fieldsince, sooner or later, the choices end up affecting everyone's life. This participation should be based on scientific knowledge acquired at school and the relevant analysis of information received about the advances of science and technology.

The participation of Brazil in the OECD assessment, since its first edition in 2000, made it possible to overview the Brazilian scientific literacy in an internationally comparative perspective. Specifically, this study used the PISA 2006 data, due to the fact that in this edition science was evaluated in more detail. Besides the global scale, in the 2006 edition, it was possible to evaluate the participating countries performance also in specific scientific competencies. The emphasis on this area of knowledge was again the focus of the programme in 2015 and that makes the theme very new and recurrent. The results of that edition, however, were not released yet and are expected in December 2016.

The main goal here is to understand how scientifically prepared are the young Brazilians who participated in PISA 2006. For this, this study sought to answer the following research questions: (a) how are the Brazilian students ranked in the international context in terms of scientific literacy of PISA?; (b) Do Brazilian students' contextual characteristics, such as their school administrative dependence and socio-economic status, impact their results in Science? To continue the discussion and answer the mentioned research questions, the following text is organized into three sections following this brief introduction. In the sequence the methodological approach adopted here is presented, then the results and finally the conclusions.

METHODOLOGY

To answer the research questions, initially, the average performance of students in the science test was analyzed in order to identify Brazil's position on the scale of PISA compared to other participating countries. After that a linear regression model was implemented to analyze the impact of some independent variables in Brazilian students' science proficiency. In particular, the study sought to verify if the socio-economic profile of students and their schools' administrative dependence were able to explain the differences in Science Proficiency (Chart 1). The implemented model here can be expressed by the expression: $Proficiency = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + e$, where Proficiency is the country grade in Science, $_{X1, X2,}$ ... are the explicative variables of the model and $\beta_{0,} \beta_{1,} \beta_{2,}$ ... are the unknown parameters to be estimated.

Chart 1. Variables considered in the study, their definitions, values and notes.

Variable	Definition	Values	Notes
Proficiency in Science (Proficiency)	Indicates Proficiency in science. It is an independent estimation of the student performance in science.	Continuous	Variable built by the PISA Consortium through The Item Response Theory (IRT)
Student Socio-economic Status (SSS)	Indicates economic, social and cultural status of the students. It is composed from aspects like home possessions, highest occupational status and educational level of the parents	1=Very Low 2= Low 3=Medium 4=High	Variable built by the PISA Consortium through the IRT
School Administrative Dependence (SAD)	Indicates whether schools are private or public	1 = public 2 = private.	The variable was aggregated to the student base and then recoded

RESULTS AND DISCUSSION

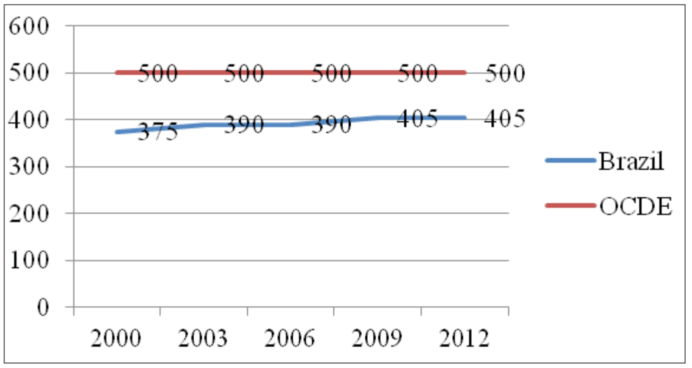
During most of the twentieth century, Brazil had quite unfavorable educational indicators, not only in comparison with European countries, but also compared to its neighbors in Latin America (Franco; Ortigão; Albernaz; Bonamino; Aguiar; Alves; Satyro, 2007). The results obtained by Brazilian students place the country at a disadvantage when compared to almost every country participating in PISA. The results of this performance evaluation in every knowledge domain are provided in a range in which the average of the OECD countries is standardized at 500, with a standard deviation of 100. This means that about two-thirds of the participant students obtained a score between 400 and 600 points.

Analysis of the overall results of PISA shows that the Brazilian performance in Science has improved since 2006 until 2012 from 390 to 405 score points (Graph 1), showing an annualized change of 2.3 score points (OCDE, 2013). Roughly half of this increase, according to OCDE (2013), can be accounted for by changes in the demographic and socio-economic composition of the student population. This mean is below the OECD mean and comparable with Argentina, Colombia, Jordan and Tunisia. Among Latin American countries, Brazil performs below Chile, Costa Rica, Uruguay and Mexico, but above Peru.

About 60% of students in Brazil are low performers in Science, which means that, at best, they can present scientific explanations that are obvious and explicitly highlighted. The percentage of students who exceed the baseline level of Proficiency in Science increased 7.3% between 2006 and 2012 (OCDE, 2013). Performance gains have been most notable among the lowest performing students (at the 10th and 25th percentile), similar to what is observed in mathematics and reading. Very few students (0.3%) in Brazil are top performers in science, which means that they can identify, explain and apply scientific knowledge and knowledge about science in a variety of life situations perceived as complex.

When comparing the mean obtained by Brazil (390) with the other countries participating in PISA 2006, it is obvious that the country's overall performance in Science is not good. Brazil was among the countries with lower performance, ranking 52.[nd] place among 57 countries administering the test, ahead only of Colombia (the 53.[rd]) when compared to its South American neighbors that have analogous socio-economic realities. Among the South American participating countries, only Chile and Uruguay have surpassed the barrier of 400 points, obtaining the 40.[th] and 43.[rd] positions, respectively. In first place is Finland with 563 points and last, Kyrgyzstan with 322.

1 Highlighted the president of the Brazilian Society for the Progress of Science (SBPC), Helena Nader, during the opening ceremony of the 65th annual meeting of the organization in the capital of Pernambuco/Brazil. Available in: http://memoria.ebc.com.br/agenciabrasil/noticia/2013-07-22/brasil-e-responsavel-por-27-da-producao-cientifica-mundial-destaca-presidente-da-sbpc.Accessed on 12/15/2015.



Graph 1. Evolution of Brazil and OCDE Science performance in all PISA editions.

The national report produced by the Instituto Nacional de Estatísticas Educacionais (INEP) to treat the PISA 2006 data (BRASIL, 2008) indicates that, based on socio-economic and cultural level indicators, it would be unreasonable to expect that the performance of Brazilian students be similar to the average of all OECD students, but that in Science it should be about 30 points higher (30% of a standard deviation) to be as expected for its average level. However, apart from socio-economic and cultural level indicators that substantially impact the results, by tradition, it is known that education in Brazil is unscientific. The education highlighted here is not the type that allows experimentation. As evidenced by Teixeira (1994) it is very abstract, focused on contents that are normally distant from students reality and minimally scientific, marked by a conservative education that allows no risk, no experiment or hypothesis testing; it is much more based on the notion of right and wrong and rooted in the conception of knowledge and use, the antithesis of what is recognized as the foundation of a quality science education.

PISA evaluated the students' competences in identifying scientific issues, in explaining phenomena scientifically and in using scientific evidence. On the competency of identifying scientific issues, Brazil reached an average of 398 points (Table 1). This is the competence in which Brazilian students show the higher skills. On the other hand, that same competence is where the OCDE students are less strong (498,79) but still with a difference that exceeds by one standard deviation the Brazilian students' mean. The greater competence of OECD students is to explain phenomena scientifically and it is very important that students understand scientific facts and theories enabling them to explain phenomena scientifically. However, they also need to be able to recognize what and how issues can be addressed in a scientific way in order to apply their abilities and scientific knowledge. About the fact of using scientific evidence, Brazilian students are particularly weak - 378.13 points.

Table 1: Average results of student s in different competencies in Science in PISA 2006 - Brazil and OECD

	Skills		
	Identifying scientific issues	Explaining phenomena scientifically	Using scientific evidence
Brazil	398.18	390.21	378.13
OECD	498.79	500.35	499.24

Source: PISA 2006 student and school database.

Currently, knowledge of and about science is more important than ever. The relevance of science to the life of any person is irrefutable and scientific knowledge is an essential tool for the achievement of individual and collective goals. This is especially important to the way Science is taught and learned. The tasks that students need to fulfill in PISA 2006 required scientific knowledge of two types: (a) knowledge *of* science, that can be divided into areas of content, such as: physical systems, living systems, earth and space systems; and (b) knowledge *about* science. Some countries have substantially higher performance in knowledge *about* science, ie knowledge of the purposes and the nature of scientific inquiry and scientific explanations, than in knowledge *of* science, knowledge of the natural world and how this is linked to different scientific subjects.

Although not reaching the average of OECD countries, Brazil managed to overcome the barrier of 400 points with respect to knowledge of Science, especially in the area of living systems. Based on the performance means of the OECD, results tend, albeit very subtly, to be better on the issues that require knowledge of science (Table 2).

Table 2: Average results of the students in the knowledge areas of PISA 2006 - Brazil and OECD

	Knowledge about Science	Knowledge of Science		
		Physical Systems	Living Systems	Earth and Space Systems
Brazil average	393.62	384.83	402.91	374.94
OECD average	499.85	500.02	501.81	499.53

Source: PISA 2006 student and school database.

The PISA national technical report (BRASIL, 2008) assures that performing better in *Knowledge of Science* suggests that the curriculum has emphasized the transmission of specific scientific knowledge. However, Brazil has better performance on issues related to knowledge about science (393.62) and the only exception is in the mean achieved in the area of living systems. This knowledge covers issues related to understanding the nature of scientific work and scientific thinking. In countries like Brazil where the literature points out and criticizes a curriculum that emphasizes only the transmission of knowledge, without promoting situations where this knowledge is mobilized (See Carnoy with Gove and Marshall, 2007), such a result is somehow surprising.

To facilitate interpretation of the results, PISA established in each domain of the evaluation areas various levels of performance, based on the classification points or proficiency associated with skills that students must have to achieve a corresponding score. According to the OECD itself (2007), the classification has two purposes: to catagorize student performance and to describe what they are capable of. The PISA Science scale has six levels of proficiency, from Level 1 to Level 6, but here, a Level 0 was included, which represents the students group that did not reach the first level of Proficiency proposed by the programme. The biggest percentages of Brazilian students, more than 60%, are concentrated in the lower range levels of the programme, levels 0 and 1 (Table 3).

Table 3. Distribution of students in the Science performance levels in PISA 2006-Brazil and OECD

	Proficiency levels in Science						
	Level 0 (Below 357.77)	Level 1 (From 357.77 to 420.07)	Level 2 (From 420.07 to 482.38)	Level 3 (From 482.38 to 544.68)	Level 4 (From 544.68 to 606.99)	Level 5 (From 606.99 to 669.3)	Level 6 (above 669.3)
Brazil	27.9	33.1	23.8	11.3	3.4	0.5	0
OECD	5.2	14.1	24.0	27.4	20.3	7.7	1.3

Source: PISA 2006 student and school database.

In large-scale assessments, such as PISA, it is anticipated that few students reach higher levels. It is expected that most of the students can reach levels two or three in the Proficiency scale, but such achievement is not reached by the participating Brazilian students in the Science PISA 2006. The reciprocal is true when attention is given to other areas evaluated by the programme in that same edition: reading and mathematics. The percentage of students under level one in reading is around 28% and over 46% in mathematics (OCDE, 2007). Students that are below the Proficiency level one are not able to perform the simplest tasks that PISA requests. This does not mean, of course, that they are completely unable to perform any task. Certainly, this result should be viewed with caution, especially when compared to the mean of OECD member countries. After all, since the

1960s the educational literature has reported the strong influence of socio-economic and cultural factors on the performance of students (Coleman, 1966; see also Marks, Cresswell and Ainley, 2007).

Despite the fact that the Brazilian parameters (BRASIL, 1998) assumes that training of citizens in elementary school require full mastery of reading, writing and arithmetic, and an understanding of: the material and social environment, political system, technology, arts and the values on which the society is based, PISA 2006 data show a significant portion of the Brazilian 15-year-old students not being able to correctly answer the questions considered easy to the majority of students participating in the programme. Currently the teaching of science has little emphasis within the basic education in Brazil, despite the strong presence of technology in people's lives and the central role that technological innovation has as an element of competitiveness between companies and nations. Scientific training should be a central component of education from the early years, alongside the training in the use of language and humanities subjects.

The Brazilian participating students in PISA 2006 were mostly from public schools, around 84% of the total. The percentage distribution of the Brazilian students of public schools through the performance levels decreases as the performance levels increase (Table 4). The distribution of the Brazilian private schools' students follows OCDE expectations to large-scale assessments. The majority of students enrolled in private schools evaluated by PISA 2006 could reach the levels 2 and 3 of Proficiency in the Science scale (62.1%). However, the same did not happen to students enrolled in Brazilian public schools where students appear concentrated in the two lower levels (0 and 1) of the scale (71.2%).

Table 4. Percentage of students in each performance level of Science according to their school administrative dependence - Brazil - PISA 2006.

Proficiency levels in Science	Administrative dependence	
	Public	Private
0	35.1	4.0
1	36.1	16.3
2	21.5	35.2
3	6.0	26.9
4	1.2	15.0
5	0.1	2.5
6	0	0.1

Source: PISA 2006 student and school database.

Brazil has greatly advanced in recent decades regarding the guarantee of educational rights, however, the universal access to school must give way to the effective right to a education of quality. Already in the mid seventies, Cunha (1975) showed the education of children of the working classes/public schools, the impact of the school access mechanisms and differentiated school performance in students of the low social segment. Based on his findings, which is fairly frequent in the literature (Patto, 1996; Soares, 2004; Franco; Ortigão; Albernaz; Bonamino; Aguiar; Alves; Satyro, 2007), here in, the distribution of students is analyzed for different socio-economic status through the PISA performance levels of 2006 (Table 5).

Table 5. Percentage distribution of the students by performance level in Science and socio-economic status - Brazil - PISA 2006.

Proficiency levels in Sciences	Socio-economic Status			
	Very Low	Low	Medium	High
0	38.3	26.5	20.9	7.0
1	36.8	35.1	29.7	15.2
2	20.0	25.5	28.6	32.2
3	4.3	10.9	14.5	24.3
4	0.6	1.9	5.7	17.7
5	0	0.1	0.6	3.4
6	0	0	0	0.2
Total	100	100	100	100

Source: PISA 2006 student and school database.

The socio-economic and cultural status is a substantially determining factor in the Brazilian students' distribution among the Proficiency levels of PISA 2006 and this is also supported in the literature by several other studies such as the classical Coleman Report (Coleman, 1966). The PISA 2006 results indicate that most of the "very low socio-economic status" students (38.3%) are at the level zero and these students are not able to reach the highest levels of the scale, levels 5 and 6. On the other hand, "high socio-economic status" students reach even the highest level of scale and more than half of them (56,5%) are allocated on the levels 2 and 3 of the PISA Scientific Literacy scale as expected by OCDE. Moved by the interest in the intensity or impact of the association between the dependent variable "proficiency" and the explanatory variables "administrative dependence" and "socio-economic status" a linear regression model was implemented.

Table 6. Regression model results (mean and standard deviation) for Brazilian participant students in PISA 2006.

Variables	Model 0	Model 1	Model 2
Proficiency in Science	390(89.3)	480.17(2.1)	506.4(2.7)
Public school		-111.9(2.3)	-81.0(2.7)
SSA Very Low **SSA Low**			-68.0(3.3) -47.4(3.5)
SSA Medium			-38.7(3.4)
R2		0.206	0.245

The science proficiency of the Brazilian students that attended a private school in the PISA 2006 was 480.2 (constant of model 1 – Table 6). Value for the mean would allocate Brazilian students at level two of the scale where students have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving. Being a student of a public school, though, decreases the proficiency mean of a Brazilian student in Science PISA 2006 up to 111.9 points, taking them to an approximate Proficiency of 367.9 and fall of a performance level. Finally, with concern to model 1, the only fact of being a Brazilian student from a public school in PISA 2006 explains up to 20% of the whole variance in the Brazilian students Proficiency in Science (R2 = 0.206).

OECD (2004) indicates that Brazil is a country in which there is a stronger correlation between the socio-economic and cultural level of the student school conditions and school effectiveness. Therefore, the correlation between proficiency, student school administrative dependence and socio-economic status was tested (Model 2). As a result, the magnitude of the relationship between the variables became even stronger by including aspects of students socio-economic level. The total variance of the Brazilian students proficiency in science is explained by approximately 25% (R2 =0.245) when considering students attending public schools and allocated on very low, low and medium socio-economic status compared to the mean represented here by private schools and high socio-economic status students. Brazilian private school and high socio-economic status students in PISA 2006 have a proficiency in science that reaches 506.4 points. Such performance places the students in the level 3 of PISA scale. A percentage of 56.7% of the students across the OECD can perform tasks at least at Level 3 but in Brazil it is only possible for students enrolled in private schools and with a high socio-economic status, which is only 4% of the Brazilian sample in PISA. At Level 3, students can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge.

CONCLUSIONS

This study aimed to look a little deeper into the performance in science of the Brazilian students in the PISA, raise questions and make some reflections about the above mentioned results. In general, the results reproduce the usual findings of the literature that claims that the social, scientific and technological development of Brazil requires a major overhaul of the educational structure in the country (See Schwartzman, 2004; Carnoy with Gove and Marshall, 2007; Barros and Ferreira, 2009).

The results obtained by the Brazilian students place the country at a disadvantageous position compared to almost every country participating in PISA. Brazil was the 52nd country in scientific competence among the 57 participants in PISA 2006. By all means, the country is placed in the level 1 of the PISA performance scale, but there is still a significant margin of Brazilian students who cannot even achieve this, which is the lower level considered by the programme. It was not the goal here, however, to develop a comparative study between Brazil and the other countries participating in this programme. Recognizing and taking into consideration the socio-economic and cultural differences among the various participating countries was not done in this study. Although rudimentary, this study identified the effect on student performance of the socio-economic background and the school administrative dependence to which Brazilian students are exposed. Variables such as color, sex, grade failure, etc., are also known to be related to student performance variance and should also be investigated in a larger scope study.

The 2006 PISA data showed that students not enrolled in a private school and who do not come from high-income families have a considerable disadvantage in science. It also showed that the fact of being enrolled in a public school is alone substantially enough to explain the variance of the mean

performance in science of Brazilian students. Science education is important for citizens to help them face new challenges and new work opportunities as the modern world changes around them. This education is a significant step towards securing a better future for all (Cury, 2002). The right to education and quality education is one of those steps that have not lost importance nor lost its relevance.

AKNOWLEDGEMENTS

To Vedrana Ljuljovic for the critical reading of the manuscript and to FAPERJ - Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro for the grant.

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Received 4-06-2016 /Approved 15-05-2017

Intelligent tutorial system for learning of basic and operational Math

Sistema tutorial inteligente para la enseñanza de las matemáticas básicas y operativas

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Abstract

The basic math are the first encounter of students with university mathematics, which will enable them to acquire the fundamentals to support more advanced courses, such as calculus, statistics, physics, chemistry, among others. Here the importance of the teacher to provide an adequate mathematical education is important. Thanks to information and communication technologies (ICT), many tools and teaching strategies involve the use of electronic and digital resources (m-learning, b-learning, e-learning, etc.) to enhance the learning processes. Intelligent Tutoring Systems (ITS) extend traditional content computerized learning systems by adding intelligence to improve the effectiveness of a learner's experience. The main objective of this paper is to present the intelligent tutorial system "Cyber-Math", which brings together the topics and theoretical concepts of basic mathematics, which allow the student to learn at their own pace, because it can be accessed at any time and place if there is access to the internet. This paper concludes that the intelligent tutorial systems can transform the traditional teaching – learning model to a flexible, agile and didactic model.

Key words: *artificial intelligence, education, mathematics, m learning, ICT.*

Resumen

Las matemáticas básicas y operativas es el primer encuentro de los estudiantes con las matemáticas de la universidad, la cual les permitirá adquirir los fundamentos básicos para abordar cursos más avanzados, tales como cálculo, estadística, física, química, entre otros, de aquí la importancia que tiene el docente de impartir una adecuada formación matemática. En la actualidad, gracias a las tecnologías de la información y la comunicación (TIC), existe una alta diversidad de técnicas y métodos de enseñanza de la matemática que involucra el uso de recursos electrónicos y digitales (m-learning, b–learning, e-learning, etc), facilitando el proceso enseñanza

– aprendizaje. Este trabajo, tiene como objetivo principal presentar el sistema tutorial "Cyber-Math", el cual reúne las temáticas y conceptos teóricos de las matemáticas básicas y operativas que le permite al estudiante interactuar con las matemáticas, ya que cuenta con la posibilidad de acceder al mismo en el momento y lugar que desee solo con tener acceso a internet. Con este trabajo se concluye que los sistemas tutoriados permiten transformar el modelo tradicional de enseñanza – aprendizaje, en un modelo ágil, flexible y didáctico.

Palabras clave: *educación, matemáticas, m-learning, inteligencia artificial, TIC.*

INTRODUCTION

Intelligent tutorial systems (ITS) are a branch of the applied artificial intelligence (AI), whose main objective is to simulate the process of teaching of an expert in a specific area of knowledge, both in the domain of a specific topic as in the aspects related to pedagogy and in communicating with the user (Murray, 2003). The ITS are designed to guide the learning process of a user at any time and place, without the need to interact directly with an expert (Q Kalhoro, 2010). Interactive learning environments that support the acquisition of cognitive skills must provide opportunities for the learner to practice the target skill (Mitrovic, Ohlsson, & Barrow, 2013).

The teaching of basic mathematics in higher education has become a complex task, due to the amount of conceptual and procedural gaps that are evident in the majority of university students in first semesters. For this reason, the mathematical teachers have the need to repeat or reinforce mathematical contents of the high school, generating delays in the development of their courses. "*Cyber-Math*" allows the user to acquire or relearn the skills of basic and operational mathematics. This paper concludes that the (ITS) facilitate the learning process in any area of knowledge and make it possible to transform the traditional educational model into a versatile, flexible and didactic model.

INTELLIGENT TUTORING SYSTEMS

Intelligent tutoring systems (ITS) were used for the first time in the year 1970, as a way of providing greater flexibility to the learning strategy and achieve a better interaction with the user (Aguilar, Muñoz, Noda, Bruno, & Moreno, 2008). The ITS have provided a fertile ground for research in artificial intelligence (AI) over the past twenty-five years (Corbett & Koedinger, 1997). The main objective of the ITS is to capture the knowledge of experts to create dynamic interactions with users, enabling them to identify their strengths and weaknesses without having to interact directly with an expert human (Aguilar et al., 2011). ITS are sophisticated software systems that can provide personalized instruction to students, in some respect similar to one-on-one tutoring. Many of these systems have been shown to be very effective in procedural domains such as algebra, physics, etc. (Gutierrez & Atkinson, 2011). In many experiments, ITS induced learning gains higher than those measured in a classroom environment, but lower than those obtained with one-on-one interactions with human tutors (Gutierrez & Atkinson, 2011). ITS foster and assess learning through adaptive interaction between the student and the system, and the instruction contains both domain-specific pedagogical knowledge and knowledge of the learner (Nkambou, Bourdeau, & Mizoguchi, 2010) and (Sanchez, Bartel, Brown, & DeRosier, 2014).

The ITS are education systems based on computers that have models of instruction of content that specify what and how to teach (Murray, 2003). These have the ability to make inferences about the thematic domain in order to dynamically adapt its content, enabling students to learn by doing in realistic and meaningful contexts, and have more control over their learning (Murray, 2003). The main advantage of the ITS in comparison with systems traditional tutorials, lies in its flexibility, in both the approach and in the adaptation to the student. The traditional tutorials systems contain a large amount of rules and information, which can generate confusion (Aguilar et al., 2011).

The design of the ITS is based on the fundamental assumption that students learn better in situations that are closer to the situations in which they are going to use their knowledge, i.e., learn by doing, committing errors, and building knowledge (Ferreira & Atkinson, 2009). In summary, the ITS have the potential to introduce advances in the field of learning and education (Ramesh & Rao, 2012) and allow that learning to be performed at any time and place (Quratulain Kalhoro, Chowdhry, Abbase, & Abbasi, 2010). ITS offer strong learning gains, but are a class of technology traditionally designed for most-developed countries (Nye, 2015). ITS rely on detailed domain-knowledge which is hard to obtain and difficult to encode (Paassen, Mokbel, & Hammer, 2016). The main components of an ITS are:

Domain Model: consists of a representation of the domain to be taught (Virvou & Sidiropoulos, 2013).

Student Model: stores information about the student's performance or behaviors, including his/her knowledge level, his/her preferences, his/her learning history and helps the ITS to personalize the teaching strategy (Virvou & Sidiropoulos, 2013).

Teaching Model: contains a representation of the teaching strategies of the system and provides adaptive instructions to the students (Virvou & Sidiropoulos, 2013).

User Interface: provides the means for the student to interact with the ITS (Virvou & Sidiropoulos, 2013).

Importance of ITS in math and science

In the state of the art review it was found that the use of ITS in the teaching of exact and natural sciences: mathematics, biology, chemistry and physics are of great utility. Prior research has shown that students learn from ITS (Millis, Forsyth, Wallace, Graesser, & Timmins, 2016). For example, results from two pilot studies done in the lab and in the field with altogether 99 undergraduates suggest that ITS leads to significant and large learning gains on chemistry knowledge (Rau, Michaelis, & Fay, 2015). ITS produced statistically and practically meaningful learning gains on measures of arithmetic and algebra knowledge (Sabo, Atkinson, Barrus, Joseph, & Perez, 2013). Table 1, presents some educational software in math and science:

Name	Area	Developer
Calculus Math App Lite	Calculus	Neu Media Technology
Operation Math	Basic math	Spinlight
Math Academy	Basic math	SCIMOB
Biology	Biology	MoboTech
O-Level Biology	Biology	JSL Educational Services
O-Level Chemistry	Chemistry	JSL Educational Services
O-Level Physics	Physics	JSL Educational Services
Physics	Basic Physics	Diablo code

M - learning applications for the teaching of basic mathematics: related works

In this section, presents the search method used to identify works related with basic math applications for mobile devices. A search of literature reviews, articles, conference proceedings, abstracts and publications was developed in specialized databases. In addition, we reviewed articles published in the following journals: *Journal of Computer Assisted Learning (JCAL), Computers and Education, Journal of the Learning Sciences, International Journal of Mobile Learning and Organization, International, Journal of Computer-Supported, Collaborative Learning e International Journal of Learning Technology.*

The range of dates was understood from the year 2010 until the year 2015. In total, we inspected 44 conference publications of m-learning and 11 articles from specialized journals. The keywords used were: *education, intelligent tutoring systems, mathematics, m-learning applications.* In total we studied 55 publications. Search equations used were:

(TITLE-ABS-KEY (m-learning) OR (education) AND (((mathematics) OR (((ITS) OR ((basic) OR (applications)))) >2009

(TITLE-ABS-KEY (m-learning) AND (education) AND (((mathematics) AND (((ITS) AND ((basic) AND (applications)))) >2009

(TITLE-ABS-KEY (m-learning) AND (education) AND (((mathematics) OR (((ITS) AND ((basic) OR (applications)))) >2009

(TITLE-ABS-KEY (m-learning) AND (education) AND (((mathematics) AND (((ITS) AND ((basic) OR (applications)))) >2009

(TITLE-ABS-KEY (m-learning) OR (education) OR (((mathematics) OR (((ITS) OR ((basic) AND (applications)))) >2009

METHODOLOGY

The methodology used for the construction of "*Cyber-Math*" was the systematic literature review (SLR), systematic, auditable, and organized process that seeks to respond to one or more research questions (Kitchenham et al., 2009). A RSL is a means to identify, assess and interpret all relevant research available related to a question of research, thematic area or phenomenon of interest. The individual studies that serve as the basis for the realization of a RSL are called primary studies, the RSL alone is considered as a secondary study (Staples & Niazi, 2007). According to Kitchenham (2009), the steps of a RSL are the following:

- *Planning the review*: the output from this phase is a systematic review protocol that defines the purpose and procedures for the review.
- *Conducting the review*: this phase ultimately generates final results, but also generates the following intermediate artifacts: the initial search record and archive, the list of selected publications, records of quality assessments, and extracted data for each of the selected publications.
- *Reporting the review:* reporting the review is a single stage phase. Usually, systematic reviews are reported using two formats: in a technical report and in a journal or conference papers. The structure and contents of reports is presented in the guidelines

The research question considered in this work was *Q1. What are the main topics and theories of basic mathematics that must know university students?* The keywords used were *Intelligent Tutoring Systems, Mathematics, M-learning.* Additionally, we searched with these words mixed together. The search equation used was:

(6) (TITLE-ABS-KEY (intelligent tutoring systems)) AND ((mathematics)) AND (m- learning) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "MATH"))

The range of publication dates considered in the review was understood from the year 2010 until the year 2015. In total were collected eight publications between articles, conference papers, summaries, chapters of books and articles in development. Table 2 presents the number of publications by type collected in the review of the state of the art.

Table 2. Number of publications

Document Type	Documents	Bibliographic description
Conference paper	5	Glavinic, Rosic, & Zelic (2007) Glavinic, Rosic, & Zelic (2008a) Glavinic, Rosic, & Zelic (2008b) Henry & Sankaranarayanan (2009) Nye (2013)
Article	2	Khemaja & Taamallah (2016) Nye (2015)
Review	1	Kaklauskas, A., Kuzminske, A., Zavadskas, E., Daniunas, A., Kaklauskas, G., Seniut, M., Cerkauskiene, R. (2015)
Total	8	

Source: scopus

Additionally, a search of gray literature was performed, were collected 17 manuals published by Colombian universities, which were used for the construction of the knowledge base .

Design and structure

"Cyber – Math" was developed with the Xerte software, which provides a comprehensive set of open source tools for developers and creators of interactive didactical material (Xerte, 2015). Xerte is aimed at developers of interactive content who will create sophisticated content with some scripting. This software can be downloaded in the next address: http://www.xerte.org.uk/index.php?lang=es. The user must register and download the file *Xerte Desktop.* See Fig 1:

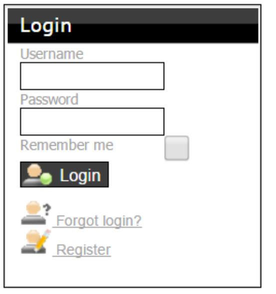


Fig 1: Access. Source: Xerte

Once downloaded and installed the program, the user must click on the option "Page Templates". See Fig 2:

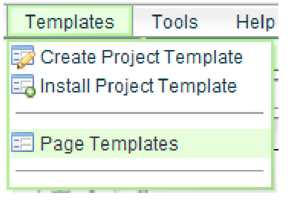


Fig 2: Templates. Source: Xerte

The program displays in the menu bar the options: File (New Project, Open, Save, Exit), View (Preview), Publish (Publish, Package), and Help. The toolbar contains three buttons: Insert (Text, Multimedia, Interactivity, Games, Connectors, Navigators and Misc), Copy, Delete, Optional properties, Add and Save. See Fig 3:

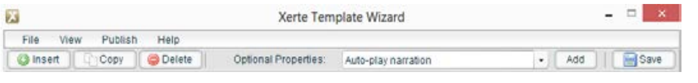


Fig 3. Menu and toolbar. Source: Xerte

The elements that are added to the LO is stored in the left-hand side. See Fig 4:

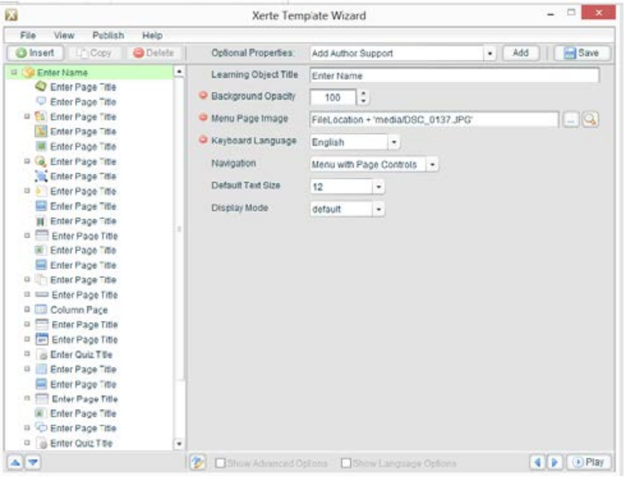


Fig 4. Elements. Source: Xerte

The user must configure the following items: background opacity (0 - 100), background image, language (English, French, German, Italian, Croatian) learning object title, navigation (linear, menu, menu with page controls), text size (10 – 36), display mode (full screen, fill window, default), custom interface, glossary, help file, icon, keyboard language, media file, media image, style-sheet. To save the changes click on "Save". See Fig 5:

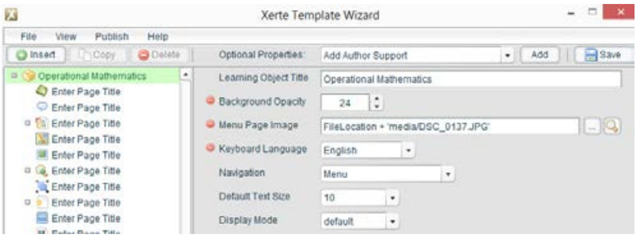


Fig 5. Configuration. Source: Xerte

To publish the learning object give click "Publish". See Fig 6:

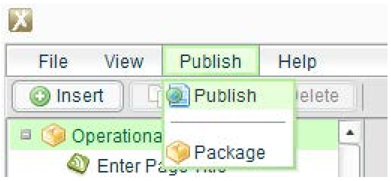


Fig 6. Publication. Source: Xerte

The "Title" element allows you to add a title to it, the user must specify the font size (20-70). Fig 7:

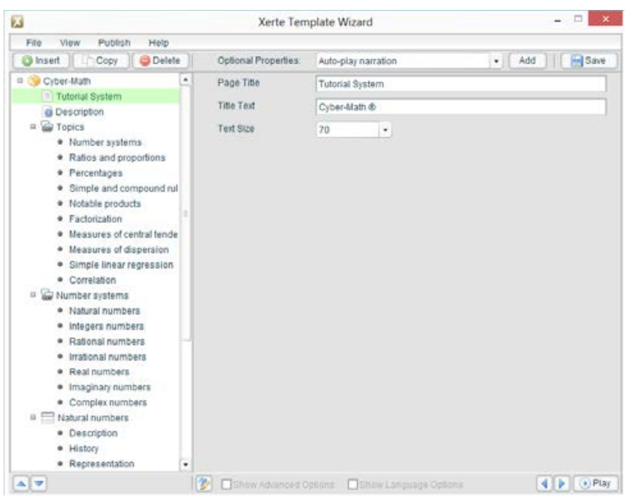


Fig 7. Title element. Source: Xerte

The "Description" element allows you to specify: page title, goals header, audience header, target audience, pre-requisites header, pre –requisites, how to reader and how to use. See Fig 8:

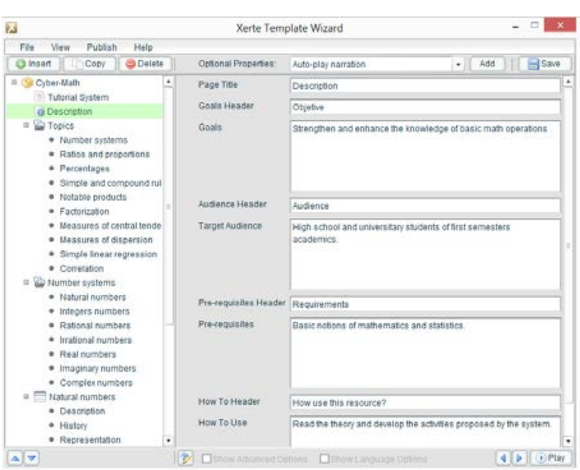


Fig 8. Description. Source: Xerte

The "Topics" element allows you to create the content table of the LO . The items redirected the user to the content that you want to know. See Fig 9:

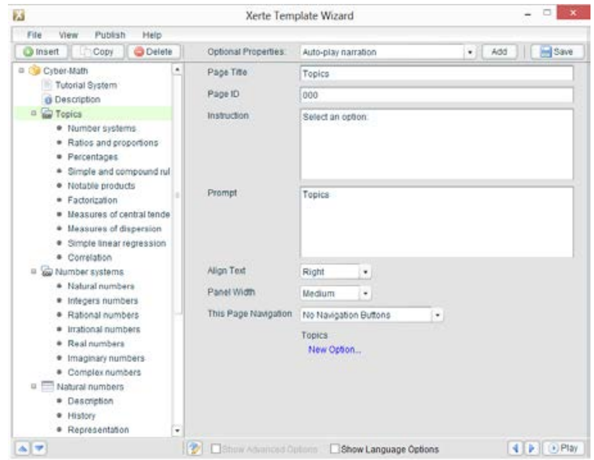


Fig 9. Topics. Source: Xerte

To create activities you must select in the "Insert" menu one of the next options: annotated diagram, button sequence, categories, dialog, drag and drop labelling, gap fill, hotspot image, and others activities. For example, Fig 10 presents a "Dialog" activity. In the section "Text" write the instructions for the user. See Fig 10:

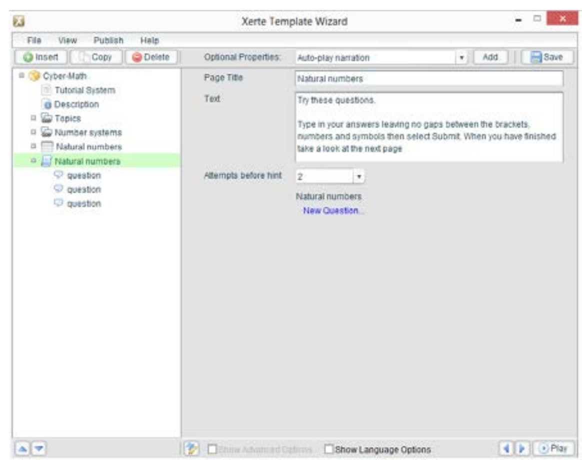


Fig 10. Topics. Source: Xerte

In the section "Question", write the question, in the section "Answer", write the correct answer and a brief "Hint". See Fig 11:

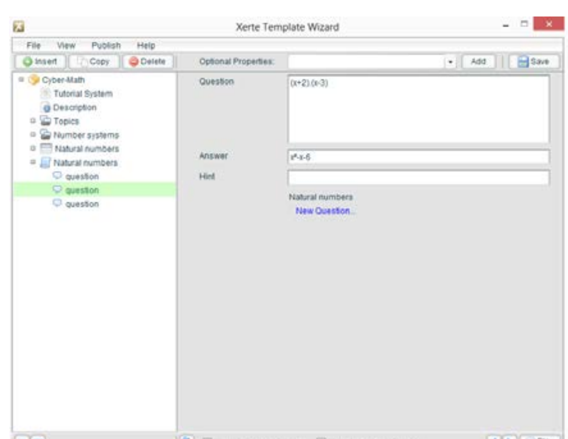


Fig 11. Topics. Source: Xerte

Similarly, the user can add other types of activities. To display the LO must press the "Play" button located in the bottom right.

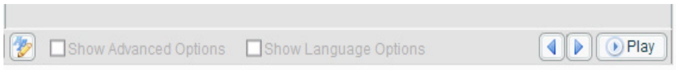


Fig 12: Display. Source: Xerte

METHODOLOGY

"*Cyber-Math*" works for mobile devices with Android and iOS operating systems with access to the internet and can be used on personal computers and laptops. Can be accessed from any browser (Google Chrome, Mozilla Firefox, Opera, Safari, Internet Explorer). The mobile device or computer must have installed the version 11.1 of Adobe Flash Player. To use it, you must access the following link: http://cybermath.wixsite.com/mobile ."*Cyber-Math*" presents the theory, concepts and fundamental notions that students must know. Fig 13 presents the initial interface of the system.

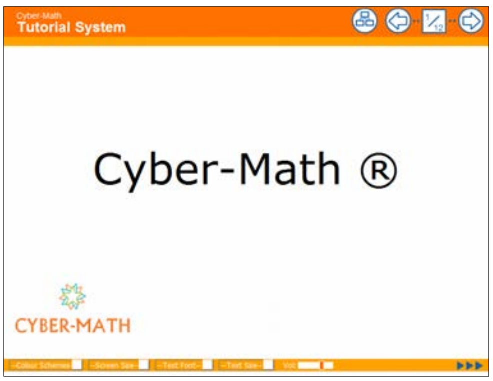


Fig 13: initial interface

Fig 14, presents the second interface, objectives, audience and how to use it.

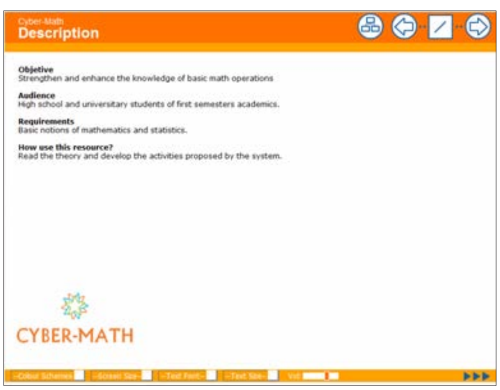


Fig 14: second interface

The Domain Model (DM) of "Cyber-Math" gathers the topics about the basic concepts of a basic mathematics course. The contents of the (DM) are: number systems, ratios and proportions, percentages, simple and compound rule of three, notable products, factorization, measures of central tendency, and measures of dispersion, simple linear regression and correlation. Each topic contains theory, exercises and test. Fig 15, presents the first activity proposed by the system belonging to the factorization topic:

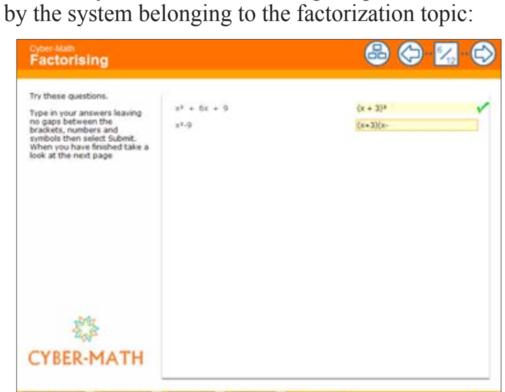


Fig 15: activity fifth

Description of pedagogical experiment

A test was conducted with 60 students of the course "Basic Mathematics" in the "Fundación Universitaria Luis Amigó" in Medellin, Colombia about notable products and quotients. Two groups A and B were created with the same amount of students (30 students). The students of the group A used "Cyber-Math" in their mobile devices (Iphone, Ipad, Smartphone, Tablet) and Laptops, in the group B the students received master classes. The test contained 10 questions and 50 minutes duration. The score were evaluated on a scale from 0.0 to 5.0. The mean ($\bar{X}$) and the Standard Deviation (S) of each group are presented below:

$$\bar{X}_A = \frac{\sum_{i=1}^{n} x_i}{n} = 4{,}07 \qquad S_A = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} = 0{,}25$$

$$\bar{X}_B = \frac{\sum_{i=1}^{n} x_i}{n} = 3{,}63 \qquad S_B = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} = 0.35$$

Table 3. Descriptive statistics

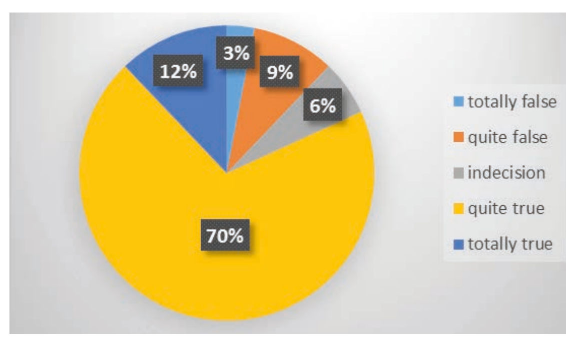
Group A		Group B	
Mean	4,07	Mean	3,63
Typical error		Typical Error	0,06
0,04		Median	3,65
Median	4,0	Mode	3,70
Mode	4,0	Standard Deviation	0,35
Standard Deviation	0,25	Variance	0,12
Variance	0,06	Range	1,4
Range	1.1	Mín	2,8
Mín	3,5	Max	4,2
Max	4,6		

The students of the group A had better scores than students of group B ($\bar{X}_A > \bar{X}_B$). The group B presented greater dispersion ($S_A < S_B$).

Opinions of teachers and students

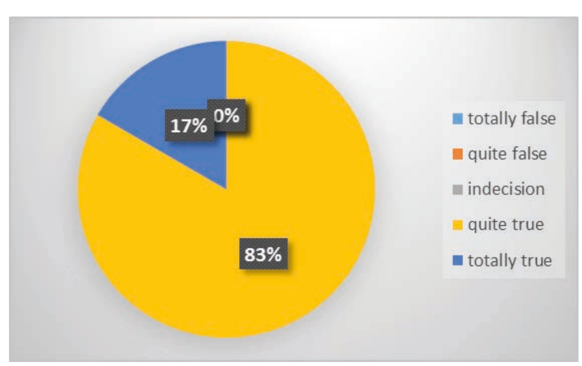
A satisfaction test was conducted to the 30 students who used "Cyber-Math" and the teacher of the course who performed the test (See Annex 1).

1. "*Cyber-Math*" contains enough information about the topic?

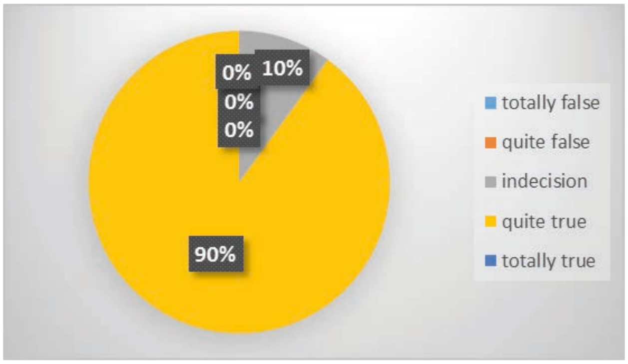


The 70% of students selected the option quite true, 12% totally true, 9% quite false, 6% indecision and 3% totally false.

Q2. The graphical interface of "*Cyber-Math*" is appropriate?

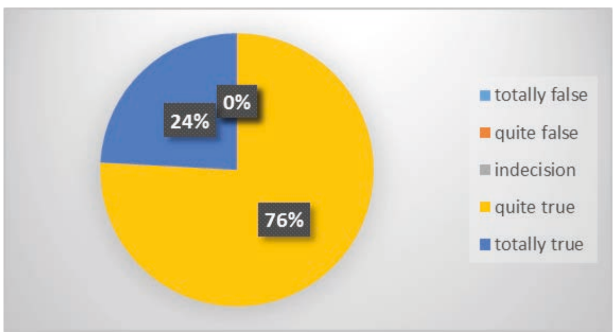


The 83% of students selected the option quite true and 17% totally true.
Q3. The videos and animations of "*Cyber-Math*" are appropriate?

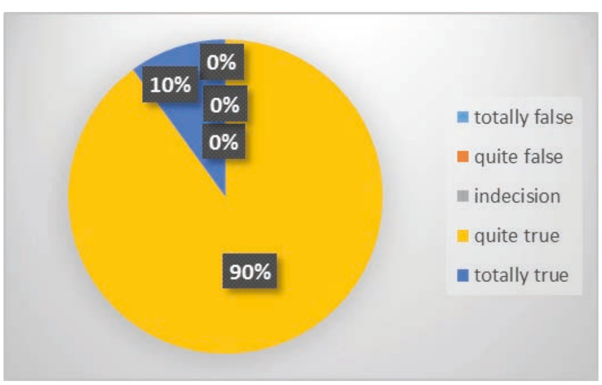


The 90% of students selected the option quite true and 10 % indecision.

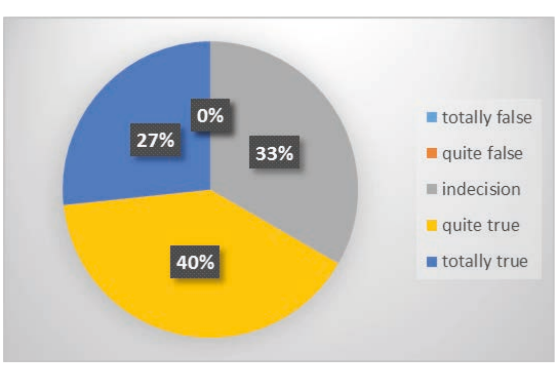
Q4. The graphics of "*Cyber-Math*" are appropriate?



The 76% of students selected the option quite true and 24% totally true.
Q5. The theoretical contents of "*Cyber-Math*" are appropriate?

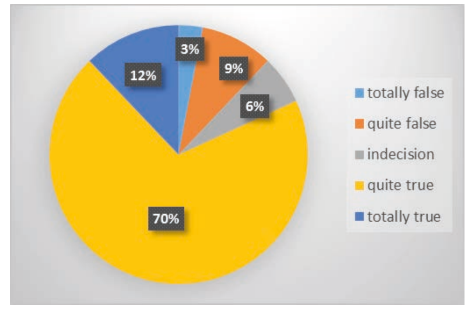


The 90% of students selected the option quite true and 10% totally true.
Q6. The links of "*Cyber-Math*" are appropriate?

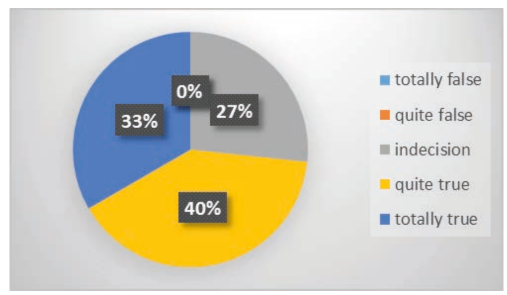


The 40% of students selected the option quite true, 33% indecision and 27 % totally true.

Q7. The proposed activities are consistent with the purpose and contents of "*Cyber-Math*"?

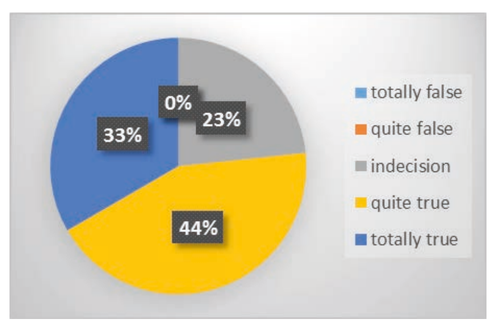


The 70% of students selected the option quite true, 12% totally true, 9% quite false, 6% indecision and 3% totally false.
Q8. The development of the activities allow learning to be consistent with the proposed objectives?

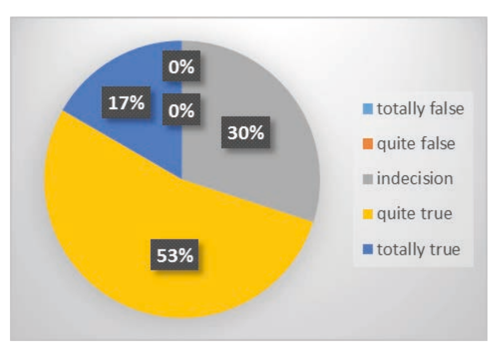


The 40% of students selected the option quite true, 33% totally true and 27% indecision.

Q9. The resources of practice and evaluation allow appropriating the contents of "*Cyber-Math*"?



The 44% of students selected the option quite true, 33% totally true and 23% indecision.
Q10. The use of "*Cyber-Math*" is easy and fun?



The 53% of students selected the option quite true, 30% indecision and 17% totally true.

The majority of students said that they could study with their smart phones and mobile devices without having to go in person where the teacher, the ITS gave them feedbacks that allowed them to identify their errors. They also expressed appreciation for the activities and interactive resources of the ITS.

The teacher of the course said that the students were more attracted and motivated to use "Cyber-Math" than receiving a master class. The integration of ITS with mobile devices allowed students to familiarize more easily with the thematic evaluated. However, some students found it difficult to adopt the ITS and requested personalized advice.

CONCLUSIONS

This paper presents the development of the ITS "Cyber - Math", oriented to the teaching and learning of basic and operational math. It is free and works for mobile devices with access to the internet. A test of validation was conducted with 60 students in the "Fundación Universitaria Luis Amigó", in Medellin, Colombia, 30 students used "Cyber - Math", the other 30 no. The results allowed us to see that the students who used "Cyber-Math" had better results than those that did not.

ITS facilitate the learning process in any area of knowledge, since they have the ability to provide feedback and provide instructions to individual users in real time, without requiring the intervention of an expert human and so allow us to transform the traditional educational model of teaching-learning. Due to the foregoing, the learning of the mathematics can cease to be an arduous and complex task thanks to the great diversity of the aid and technological resources.

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ANNEX 1

The following 10 items are to evaluate their level of satisfaction with the use of "Cyber-Math". Select one of the 5 response options:

1 totally false
2 quite false
3 indecision
4 quite true
5 totally true

Q1. "*Cyber-Math*" contains enough information about the topic?
Q2. The graphical interface of "*Cyber-Math"* is appropriate?
Q3. The videos and animations of "*Cyber-Math*" are appropriate?
Q4. The graphics of "*Cyber-Math*" are appropriate?
Q5. The theoretical content of "*Cyber-Math*" are appropriate?
Q6. The links of "*Cyber-Math*" are appropriate?
Q7. The proposed activities are consistent with the purpose and contents of "*Cyber-Math*"?
Q8. The development of the activities allow learning to be consistent with the proposed objectives?
Q9. The resources of practice and evaluation allow appropriating the contents of "*Cyber-Math*"?
Q10. The use of "*Cyber-Math*" is easy and fun?

Received 2-10-2016 /Approved 15-05-2017

Aplicación de un aprendizaje basado en problemas en estudiantes universitarios de ingeniería del riego

Application of a problem-based learning in university students of irrigation engineering

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Resumen

En el presente artículo se presentan los resultados de un estudio realizado mediante la metodología activa de aprendizaje denominada "Aprendizaje basado en Problemas" (ABP), en estudiantes universitarios. El trabajo se ha desarrollado durante el curso 2015-16 en dos grupos de alumnos de la asignatura Ingeniería del Riego, en el Grado en Ingeniería Agrícola de la Escuela Técnica Superior de Ingeniería de la Universidad de Huelva (España). Ha comprendido la aplicación de la metodología didáctica específica y su evaluación, detallándose el problema estructurante diseñado y su división en subproblemas. La evaluación se ha efectuado empleando un método cuasi-experimental. Entre las conclusiones se destaca que el ABP es preferible a la metodología tradicional expositiva, al resultar significativa la diferencia en adquisición de conocimientos por los estudiantes. Así mismo, se produce mejora en los planteamientos para la resolución de los problemas planteados, no sólo la diferencia en resultados numéricos finales, sino el planteamiento establecido para llegar a los mismos.

Palabras clave: *aprendizaje basado en problemas, formación de ingenieros, método cuasiexperimental, ingeniería del riego*

Abstract

In this paper results are shown for research carried out through active learning methodology, which is called "Problem-Based Learning" (PBL), among university students. The work was developed during the academic year 2015-16 and it *was carried out with two groups of students enrolled in the subject "Irrigation Engineering", belonging to the Agricultural Engineering Degree from the Superior Technical School of Engineering of the University of Huelva (Spain). To do so the application of specific teaching methods and evaluation were necessary, with special attention to the structuring problem and its division into sub problems. The evaluation was carried out using a quasi-experimental method. One highlight of the conclusions is that the PBL methodology is preferable to the traditional expository methodology due to the significant difference in knowledge acquisition by students. Also, improvement occurs in the approaches regarding problem resolution, not only in the difference in final numerical results, but the way they were reached. Keywords: problem-based learning, engineers training, quasi-experimental method, irrigation engineering*

Key words: *problem-based learning, engineering education, quasi-experimental method, irrigation engineering*

INTRODUCCIÓN

Las metodologías activas de aprendizaje otorgan un papel fundamental al estudiantes en su formación, ya que el desarrollo del proceso de enseñanza-aprendizaje depende en gran medida de la actitud de implicación y responsabilidad que desarrolle hacia el mismo. Los resultados de la aplicación de dichas metodologías activas son muy positivos, pues aportan al estudiante una mayor implicación, motivación e interés, mayor interiorización de los conocimientos adquiridos, mayor desarrollo de competencias profesionales y transversales, mayor integración y relación de los nuevos conocimientos con otros anteriores y una menor tasa de abandono de los estudios (Eragin, 2012; Robledo et al. 2015).

El Aprendizaje basado en Problemas (en adelante ABP); se enmarca dentro de las metodologías activas de aprendizaje. La principal característica de este método de abordar el aprendizaje activo consiste en que se plantea un problema vehicular al alumnado, sirviendo para generar la demanda por parte del mismo de una serie de conocimientos y competencias directamente relacionados con el área técnica objeto del aprendizaje. La resolución de problemas tiene un papel fundamental en cualquier nivel del sistema educativo. La destreza para resolver problemas es uno de los objetivos más importantes de la educación en general, y en la enseñanza de la ingeniería en particular. En este sentido el ABP guarda una estrecha relación con otras metodologías activas muy próximas como el método problémico (Orlik, 2002) o el aprendizaje basado en proyectos (Mettas y Constantinou, 2008.). El ABP, sin embargo, guarda ciertas características que le son propias y en puridad constituye una metodología activa con elementos específicos cuando se aplica en forma ortodoxa. Woods (2012) define en ese caso como "auténtico" ABP. Nosotros, por nuestra parte, consideramos que no existe una delimitación neta entre distintas metodologías activas existiendo elementos comunes que se combinan y recombinan entre todas ellas. Esto ha permitido una flexibilidad para ejercer su adaptación a un campo como la ingeniería, que no fue en origen el medio docente típico para la implantación del ABP. De hecho, en sus inicios el ABP comenzó a aplicarse a la enseñanza del Derecho. Pero el mayor desarrollo se dio en las Facultades de Medicina, un campo tradicionalmente con fuerte implicación empírica y experimental (Barrows, 1985). El ABP en medicina tuvo como antecedente clave los trabajos de Barrows y Tamblyn (1980). Dichos autores definen al ABP como "un método de aprendizaje basado en el principio de usar problemas como punto de partida para la adquisición e integración de los nuevos conocimientos" (p. 1). La Universidad de McMaster (Canadá), entre la década de los 60 y 70, implantó el ABP como metodología docente en los estudios de medicina (Barrows, 1971). Posteriormente el ABP se fue aplicando a diferentes áreas con necesidades específicas. La migración desde la enseñanza del derecho a la medicina, y desde ésta a la ingeniería y arquitectura han acaparado una parte de las aplicaciones más interesantes, pero con algunas variaciones y una serie de adaptaciones requeridas para hacer factible su aplicación. Los elementos esenciales se mantienen: un aprendizaje centrado en el alumno, el trabajo con grupos pequeños, el docente como facilitador, el autoconocimiento y los problemas como generadores de habilidades son comunes a la Metodología didáctica específica ABP (Barrett, 2005; Rodríguez y Fernández-Batanero, 2016). En esta línea, los objetivos y tareas que se deben cumplir en el ABP incluyen el utilizar estrategias de razonamiento para proponer hipótesis explicativas; identificar necesidades de aprendizaje, y capacitar para trasladar los aprendizajes conseguidos hacia otros problemas (Branda, 2009).

Centrándonos en el ámbito de la ingeniería, tenemos que decir que la aplicación del APB en este campo ha sido más pausada con respecto al campo de la medicina (Bédard et al., 2012). Dentro de los antecedentes en la aplicación del ABP a la enseñanza de la ingeniería podemos mencionar una serie de trabajos, a modo de referencias clave que van a condicionar la investigación presente. En la formación de ingenieros con las competencias que exige el entorno laboral mencionamos el notable trabajo de Fernández y Duarte (2013). Con respecto a la forma de implantar un ABP en ingeniería y los matices requeridos existen diferentes trabajos de interés para la investigación expuesta (Basri et al., 2012; Shinde e Inamdar, 2013). La implantación del ABP en ingeniería progresa, y numerosas pruebas y evaluaciones lo atestiguan (Chau, 2005; Loncar-Vickovic et al., 2008; Mgangira, 2003; Paje et al. 2011; Yadav et al., 2011; Vega et al., 2014). Los resultados obtenidos en las diferentes pruebas no son unívocos (Ribeiro, 2005), y la puesta en práctica ha requerido en algunos casos variantes a tener en cuenta. Entre estas variantes, las hay que inciden en el papel del profesor como facilitador sustituyéndolo por un trabajo interactivo con ordenadores (Mercier y Frederiksen, 2007), aunque desde el punto de vista de los autores del presente trabajo el papel del profesor lo consideramos necesario en el ámbito que nos ocupa.

También el ABP se ha extendido a otros campos de aplicación, más allá de la medicina y la ingeniería, como por ejemplo las ciencias económicas (Santillán, 2006), la química (Lorenzo et al., 2011), ciencias ambientales (Torres, 2013) e incluso la geografía (Latasa et al., 2012) han sido objeto de diversos trabajos de referencia. Como se puede comprobar por los antecedentes mencionados, y que suponen únicamente una breve selección de trabajos, el campo de investigación relacionado con el ABP, tanto directa como transversalmente, es amplio.

En cuanto a la posible ponderación del efecto que produce un ABP en los estudiantes distintos trabajos han abordado distintos componentes. Así por ejemplo Carrión et al. (2015) se va a referir a aspectos distintos de la mera adquisición de conocimientos, como son los valores y actitudes en el ámbito de la medicina. Los autores, en otros trabajos, se han enfocado precisamente en la adquisición de conocimientos expresada por el rendimiento académico (Rodríguez, 2016; Rodríguez y Fernández Batanero, 2017). El presente trabajo, no obstante, está orientado a diferentes aspectos, con el acento puesto en las dificultades propias en el procedimiento de implantación del ABP en la Ingeniería del Riego. La herramienta de evaluación ha requerido de una adaptación conforme a los grupos en experimentación. En este sentido, podemos mencionar la investigación realizada por Latasa et al. (2012), como afín en lo que corresponde a tamaños de grupos de evaluación del ABP y al análisis de las calificaciones finales obtenidas por los sujetos participantes como variable cuantitativa de referencia. Pero en el trabajo presente, la información cualitativa aportada por el diario de clase también es importante, tal como se verá posteriormente. En el aspecto metodológico ha supuesto un añadido sobre la información cuantitativa expresada por los resultados del rendimiento académico.

Como antecedentes relacionados directa y transversalmente con el trabajo efectuado mencionamos dos estudios realizados por los autores: una investigación efectuada sobre la enseñanza de las construcciones agrarias (Rodríguez y Fernández Batanero, 2017), con el acento puesto en la evaluación cuantitativa y el instrumento de medición empleado; y una prueba piloto efectuada durante el curso 2013-14 en varias asignaturas del área de Ingeniería de la Construcción de la Universidad de Huelva, incluyendo Ingeniería del Riego (Rodríguez, 2014). En lo que corresponde a la enseñanza de Ingeniería del Riego y los resultados de la investigación que expone el presente trabajo, los aspectos procedimentales de la aplicación del ABP y la evaluación integrada con datos cuantitativos y cualitativos han sido el elemento diferenciador con respecto a otros trabajos. Se ha pretendido que al realizar una evaluación más amplia se haya permitido obtener conclusiones adicionales a las referentes al rendimiento académico. Por otro lado, y tras la prueba piloto mencionada, se detectaron dificultades específicas en la impartición de la materia que nos ocupa. Es, con diferencia, la materia sondeada con más dificultad en la implantación del ABP. Por tanto, tras detectarse dichas dificultades adicionales en la aplicación e implantación del ABP en Ingeniería del Riego se decidió volver a realizar el experimento con la experiencia previa, de la cual el presente trabajo comprende los resultados del análisis del experimento. Las experiencias previas de otros investigadores al respecto han sido tenidas en cuenta, particularmente aquellas que sirvan como experiencia en la búsqueda de mejora del proceso enseñanza-aprendizaje en ingeniería. Pero en lo que corresponde a aplicación de un ABP en Ingeniería del Riego el presente trabajo supone uno de los primeros antecedentes, exponiéndose las conclusiones derivadas de una investigación efectuada sobre implantación de un ABP en los cursos 2013-14, 2014-15 y 2015-16. Los resultados del efecto sobre el rendimiento académico en los alumnos, tras corregirse en años sucesivos la implantación del ABP en Ingeniería del Riego, se han considerado competentes, tras realizar las correcciones oportunas, los del curso 2015-16 que se adjuntan.

METODOLOGÍA

El objetivo principal que se estableció ha sido determinar si existen diferencias significativas en los aprendizajes en Ingeniería del Riego entre alumnos que han participado en un programa de enseñanza basada en un ABP, y otros alumnos que han participado en un método expositivo tradicional combinado con la realización de problemas por el docente (en adelante MET). Los objetivos específicos han comprendido: 1) establecer si el ABP es efectivo con un periodo de 10 semanas de aplicación; 2) realizar un análisis comparado entre el MET y ABP en lo que a eficacia y eficiencia se refiere -según se han precisado estos términos como veremos posteriormente-; 3) comprobar si se producen mejoras en los planteamientos para la resolución de los problemas y 4) averiguar si se reducen errores de cálculo tras un planteamiento del problema a resolver adecuado. La detección de dificultades específicas en la implantación de un ABP en Ingeniería del Riego y la forma de minorarlas ha supuesto de facto un objetivo concreto, con respecto a otras investigaciones afines de los autores. En cuanto a las Metas, vinculadas a los objetivos fijados, han sido para la investigación realizada las siguientes: 1) mejorar la eficiencia en el proceso enseñanza-aprendizaje de la asignatura de Ingeniería del Riego; 2) reducir el porcentaje de suspensos asociados a la asignatura; 3) acercar los conocimientos adquiridos a la práctica profesional real futura; 4) reducir el abandono de los estudios de ingeniería por falta de motivación del alumnado; 5) establecer una propuesta válida favorable a la implantación del ABP en ingeniería que sirva de apoyo a decisiones futuras al respecto y 6) mejorar la calidad de la enseñanza en la E.T.S.I. de la Universidad de Huelva. Estos objetivos y metas no han variado desde que se realizó el primer estudio piloto (Rodríguez, 2014), pero sí se han ido corrigiendo en su aplicación.

En cuanto al problema de investigación, se ha trabajado con dos grupos de alumnos: un grupo experimental (en adelante GE) que ha recibido un ABP como tratamiento específico docente, y un grupo de control (en adelante GC) que ha recibido un MET exclusivamente como método didáctico. En cuanto a la estructuración del problema de investigación, se ha dividido en 3 fases principales: 1) diseño de un ABP aplicado a la asignatura de Ingeniería del Riego; 2) aplicación y puesta en práctica del ABP en el GE y del MET en el GC, y 3) evaluación del ABP. La evaluación del ABP ha contado con una validación estadística mediante una técnica estadística no paramétrica adecuada para grupos reducidos de alumnos y una información descriptiva de apoyo procedente del diario de clase del profesor responsable. Para poder asegurar que los grupos que han participado en la investigación han podido (o no) ser comparables, se ha realizado un estudio de homogeneidad de muestras, resultando que los susodichos grupos efectivamente han sido comparables. En cuanto a la información procedente del diario de clase, además de los términos que posteriormente se precisarán, ha sido fundamentalmente de corte descriptivo. La información que aporta dicho diario es muy importante en aspectos contextuales, siendo orientativas y complementarias en lo que a la validación del ABP se refiere. Se justificó su empleo debido a los problemas inherentes a la impartición de la Ingeniería del Riego, con respecto a otras materias. Por tanto, la metodología concede a los resultados cuantitativos las deducciones referentes al rendimiento académico y a la información descriptiva de tipo cualitativa información útil de contexto. Las fases principales de la investigación ha requerido de ciertas operaciones. En la figura 1 se presentan las fases y operaciones de la investigación.

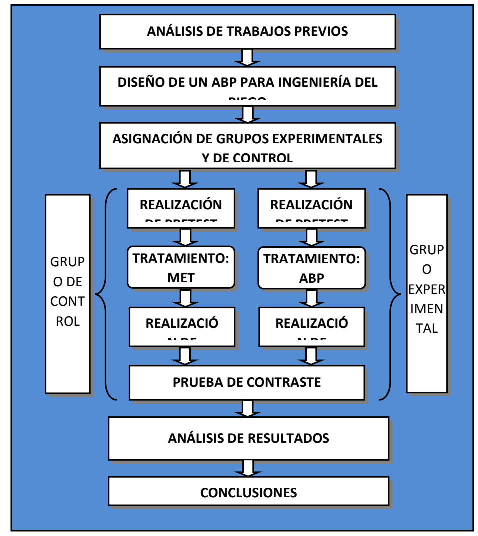

Fig. 1. Fases y Operaciones de la Investigación.

Diseño de un ABP para Ingeniería del Riego

Además del estudio de trabajos previos –en particular las conclusiones derivadas del estudio piloto referido (Rodríguez, 2014)-, el diseño del ABP para la asignatura de Ingeniería del Riego ha conllevado una detallada programación por semanas, siendo recogida dicha programación (con las pruebas de control fijadas) en la correspondiente guía docente de la asignatura. Es imprescindible un periodo de 6 semanas de aplicación de un MET común a todos los alumnos, según se determinó en el estudio piloto. En este periodo, es donde se exponen los fundamentos requeridos de la materia impartida.

Los 11 casos prácticos que comprenden el desarrollo de la asignatura conforme a un ABP son los siguientes: 1) Cálculo de canal de riego procedente de El Chanza, tramo de Aljaraque (provincia de Huelva); 2) Sistema de abastecimiento de aguas y bocas de riego (con tuberías en serie, paralelo e interconectadas) en población de La Línea de la Concepción (provincia de Cádiz); 3) Sistema de abastecimiento de aguas mallado con hipótesis de averías, dotación para riego y sistema de alcantarillado en La Gaga, Lepe (provincia de Huelva); 4) Riego ornamental en barriada “La Reconquista” de Algeciras (provincia de Cádiz); 5) Sistema de riego deportivo para campo de fútbol “La Menacha”, Algeciras (provincia de Cádiz); 6) Proyecto de puesta en riego en Zona Centro de Extremadura (provincias de Cáceres y Badajoz); 7) Sistema de riego con acequia y depósito elevado de regulación para huertas en La Línea de la Concepción, Campo de Gibraltar (provincia de Cádiz); 8) Sistema de riego deportivo para campo de golf en la costa de Huelva; 9) Sistema de riego de cobertura total en la Comarca de la Axarquía (provincia de Málaga); 10) Sistema de riego por aspersión mediante pivote central en explotación agrícola dentro de la Cuenca Hidrográfica del Tajo (provincia de Toledo) y 11) Cálculo de anillo hidráulico y del sistema de riego del Hospital Infanta Elena (provincia de Huelva). Los primeros 3 casos prácticos ayudan a reforzar los conocimientos de hidráulica, comunes con la Ingeniería Civil clásica; los casos 4, 5 y 8 se refieren a aplicaciones de riego ornamental fundamentalmente; los casos 7, 9 y 10 son diferentes aplicaciones de riego en el ámbito de la explotación agrícola alimentaria, y los casos 6 y 11 comprenden aplicaciones integrales de diferentes técnicas (aspersión, riego localizado, equipos de bombeo y otras), a gran escala regional el caso 6 y a escala de proyecto de detalle el caso 11. Las obras de drenaje (tema 20 y último de la asignatura) se dan en sesiones independientes, comunes para el GE y el GC, no siendo por tanto objeto de ABP. Como se puede intuir, la programación del ABP es ambiciosa. No obstante, en la práctica, de cada caso práctico se seleccionan a su vez subproblemas para poder hacer viable la adquisición de conocimientos conforme a los objetivos docentes con la disponibilidad temporal de la asignatura. Las guías de ayuda comprenden un material inédito de los autores, y sirven para poder seguir el desarrollo del ABP en clase. Al final del siguiente apartado se dan indicaciones con un ejemplo a modo de referencia sobre cómo poner en marcha el estudio de casos.

Aplicación y puesta en práctica del ABP para Ingeniería del Riego

Los objetivos incluidos en la guía docente de la asignatura, y a los que la metodología docente (bien sea MET o ABP) deben dar solución satisfactoria son 6: 1) Proporcionar las bases de hidráulica necesarias para el diseño y cálculo de una instalación de riego, 2) Dar a conocer al alumno los materiales y componentes habituales de las redes hidráulicas de riego, 3) Conocer los métodos de medición de caudales, 4) Conocer los fundamentos hidráulicos del flujo en lámina libre, 5) Proporcionar conocimientos básicos sobre bombas hidráulicas, 6) Poder realizar, a modo de culminación de los objetivos anteriores, el diseño y cálculo de un sistema de impulsión con red de riego. Estos objetivos son independientes del tratamiento didáctico específico aplicado y su cumplimiento conlleva la asimilación de unos conocimientos conforme al temario definido. En el caso del MET se ha procedido a exponer en clase las materias de forma pormenorizada, siendo ilustradas con problemas resueltos por el docente a medida que ha avanzado la asignatura. En cuanto al ABP la perspectiva para el alumno que recibe las clases es diferente: requiere de su participación activa. Con excepción de los fundamentos hidráulicos durante las primeras 6 semanas de clase comunes para ambos grupos, en el caso del ABP los 11 casos programados no se desgranan en unidades de conocimiento con una delimitación neta en el temario; o sea, no coinciden los 20 temas de la asignatura con los 11 casos. Algo razonable si entendemos que la actividad ingenieril requiere de una perspectiva integral del conocimiento. No obstante, algunos casos tienen más relación con ciertos temas que otros: por ejemplo, el tema 13 de céspedes deportivos tendrá una conexión muy obvia con los casos 5 y 8. Es importante para aquellos investigadores que quieran hacer su programación de ABP que entiendan que es casi imposible corresponder exactamente el temario de una asignatura con una serie de casos reales. Pero, sin menoscabo de la aserción anterior, los casos prácticos a su vez deben funcionar *como envolventes* del conocimiento que deben adquirir los alumnos. La superposición de conocimiento en los casos programados en ABP no supone un problema: supone una adecuación a la vida real. Por otra parte, dichos casos prácticos se suceden como hitos sucesivos que deben ser superados. Según se deduce del diario de clase, no hay una dificultad creciente ni una ley deducible al respecto: lo que es difícil para algunos alumnos para otros es fácil, lo que justifica en parte el trabajo en grupo a modo de oficina técnica. Los alumnos, por tanto, deben cooperar y trabajar para "sacar" adelante el subproblema seleccionado del caso concreto.

Los factores que componen la estrategia enseñanza-aprendizaje seguida en el ABP en Ingeniería del Riego no han diferido en lo esencial de otras asignaturas del área de conocimiento Ingeniería de la Construcción de la Universidad de Huelva, y se pueden consultar en los antecedentes referidos; en particular, en Rodríguez y Fernández Batanero (2017) se encuentran bastante acordes a la actualidad docente de la asignatura. La exposición detallada de los casos prácticos con la citada estrategia excede los objetivos de este trabajo. El material docente correspondiente a los casos es voluminoso en este sentido, y ha resultado del esfuerzo de años de recopilación de proyectos y estudios, una parte de autoría propia y otra cedida de proyectos externos. No obstante, a modo de ejemplo ilustrativo exponemos un extracto de la aplicación y puesta en práctica del caso práctico Nº11, con algunas informaciones extraídas del diario de clase. En forma secuencial son los 6 factores clave que componen la estrategia enseñanza-aprendizaje adoptada, teniendo en cuenta las apreciaciones de Barrows y Tamblyn (1980). La adaptación de la estrategia de enseñanza-aprendizaje al ámbito de la Ingeniería del Riego con empleo de ABP es propia de los autores y no debe considerarse tradicional. La información subsiguiente se ha completado con el registro realizado en el diario de clase, y ha comprendido 4 sesiones. Tenemos:

Desarrollo del caso práctico nº 11: Cálculo de anillo hidráulico y del sistema de riego del Hospital Infanta Elena (provincia de Huelva). 1) Se expone en un retroproyector la información útil al caso, incluyendo el problema a resolver. En el caso 11, comienza con: "Por encargo del departamento de Servicios Generales del Hospital Infanta Elena, el técnico que suscribe va a proceder a la redacción del Proyecto, que se ha denominado: Obras de Modernización de la red de riego en zonas ajardinadas del Hospital Infanta Elena de Huelva. Este Proyecto servirá de base para los trámites legales y administrativos necesarios, así como para la ejecución y dirección de las obras. Para la consecución de este objetivo, se ha planteado un estudio en tres fases: Fase I: Gabinete. Recopilación de información técnica y gráfica que sirva de base para las siguientes fases. Fase II: Campo. Recopilación de información de campo, determinación de estado actual y primeras propuestas y/o alternativas. Fase III: Gabinete. Tratamiento y análisis sistemático de la información registrada en las fases anteriores y determinación de solución óptima". Los alumnos deben percibir que el caso exige su responsabilidad para su propio aprendizaje. El docente-tutor asume un rol de *facilitador* únicamente, dejando de lado su rol tradicional. A los alumnos se les va dando la información referida, en forma tal que la disponibilidad temporal (4 sesiones) lo permita. Los subproblemas seleccionados para el curso 2015-16 del caso 11 han sido 3: a) determinación del esquema general de una parte de la red proyectada (diseño), b) cálculo del anillo hidráulico y c) cálculo del riego del ajardinamiento (selección de 3 partes con técnicas distintas de riego localizado, por aspersión y nebulización). Las sesiones fijadas para este caso han sido 4 sesiones de 2 horas. El trabajo ha sido intenso, y no ha permitido holguras en la programación. Algunos alumnos han sentido cierto estrés, pero dado que este caso es el último y uno de los más interesantes, el entrenamiento recibido en ABP durante los meses de marzo, abril y primera quincena de mayo de 2016 facilitó su abordaje. En la siguiente fase 2) se establecieron los grupos de trabajo. En ingeniería los autores recomiendan 3 ó 4 alumnos por grupo por la experiencia adquirida previamente. Los alumnos han entendido, pese a algunas reticencias, que una característica fundamental del ABP con respecto a otras metodologías activas es que en cada resolución de un caso ello implica la construcción de los grupos previamente formados para construir unos nuevos grupos de trabajo para el caso siguiente. Al finalizar cada caso práctico los estudiantes cambian de grupo y trabajan con un nuevo grupo, permitiéndoles adquirir práctica con una variedad de diferentes personas. En total habrán trabajado en 11 grupos de trabajo diferentes. En la primera sesión del caso 1, no obstante, el docente dejó que de forma natural se agruparan los alumnos, por afinidades personales. Habitualmente es frecuente la asociación por lugares de procedencia, aficiones o intereses. Se facilita así el comienzo del ABP, si bien en el caso 2, al iniciar la formación de nuevos grupos era resaltable los gestos de desagrado de algunos alumnos al tener que abandonar su cómodo y estable (pero poco interesante para ABP) grupo rígido de trabajo. Posteriormente 3) Con auxilio de una guía (previamente disponible en el repositorio digital) y que deben llevar a las aulas, la problemática propuesta representa el desafío que los estudiantes tienen que enfrentar. Tienen que repartirse el trabajo, e inclusive, modificar roles dentro del grupo, dado que los alumnos tienen más facilidades para ciertas tareas que para otras. Existe un intercambio de conocimientos. Para el diseño hidráulico de la red que compone el primer subproblema se les proporcionó información gráfica, y material de consulta a modo de referencia. El tutor no debe ceder ante la presión de dar la solución final, y debe dejar que, a pesar de ciertas fricciones en clase, los grupos intercedan por sí mismos en la búsqueda de la solución. En este sentido 4) el docente adquiere el papel de facilitador. El profesor, que asume el rol de tutor, debe procurar que los estudiantes encuentren por ellos mismos la mejor ruta de entendimiento y gestión del problema. Por ejemplo, en el caso práctico que nos ocupa (de autoría real por el docente), fue liberando progresivamente información que hizo que la solución llegara por los propios alumnos. El diseño, como característica propia, siempre tiene una componente flexible, o artística inclusive, de forma que no hubo soluciones idénticas en los 6 grupos de trabajo. Pero cada solución debió de ser viable, y fue objeto de comentario antes de pasar al siguiente subproblema. De este modo llegamos a un factor clave del ABP: 5) Los problemas generan habilidades. Y de hecho, los alumnos que han seguido ABP han aprendido por sí mismos, con una ayuda directa muy pautada, a resolver problemas de sistemas de riego. En el cálculo del anillo hidráulico (subproblema 2), se ciñeron a una única opción de diseño proporcionada por el tutor. En este caso, su resolución sí fue, a diferencia del diseño, una solución única: el diámetro óptimo y el sistema de bombas requerido (potencia, caudal, disposición en el cuadro de bombas, etc.) La colocación de una ventosa en el punto más elevado del sistema fue objeto de un pequeño acertijo en clase, pues su determinación exacta no era tan sencilla. En este sentido 6) el aprendizaje autodirigido genera nuevo conocimiento. Durante este aprendizaje autodirigido, los estudiantes han trabajado juntos, discutiendo y comparando soluciones del campo de la ingeniería. Este aspecto del ABP es para los futuros ingenieros quizás el más importante por el saber-hacer que ello ha procurado. Una vez cerrados los 3 subproblemas, el docente vuelve a tomar una actitud activa al final del estudio del caso, comentando las diferentes vicisitudes a modo de epílogo, y en forma graciable en lo posible para hacer más amenas las clases, sobre cómo cada grupo ha llegado a "su" solución, y cual debiera haber sido la solución.

Evaluación del ABP

La evaluación del ABP tiene dos componentes: una relativa al rendimiento académico y otra relativa a las dificultades de implantación específicas para Ingeniería del Riego. En consonancia con estas componentes, la información recabada en el experimento ha sido de dos tipos. Cuantitativa procedente de la validación estadística, y cualitativa procedente del diario de clase. En lo que corresponde a este último, su fundamento metodológico lo encontramos en los postulados de Hammersley y Atkinson (1994) y en el caso concreto que nos ocupa ha comprendido información descriptiva procedente de la observación participante ejercida por el profesor Rodríguez durante el curso 2015-16 como docente. La necesidad de su empleo se justificó tras detectarse dificultades propias en la impartición de la materia en cuestión en el estudio piloto correspondiente. La información recopilada en el diario de clase ha sido valiosa para intentar describir aspectos contextuales y detectar necesidades específicas, tal como veremos en la discusión. La información cuantitativa, tras su tratamiento estadístico, ha proporcionado los resultados que han dado cumplimiento al objetivo principal de la investigación referido al rendimiento académico de los alumnos.

En la aplicación del ABP han estado siempre presentes dos profesores. El proceso durante los tres cursos académicos que ha comprendido la implantación del ABP no ha sido estrictamente lineal. En algunos casos se ha requerido volver a rehacer algún paso al detectarse indicios de algún tipo de sesgo en el experimento. En este sentido la materia Ingeniería del Riego presenta dificultades adicionales con respecto a otras materias del área (construcciones agrarias, construcción y obras en el ámbito minero, etc.) Tras los resultados estadísticos y la información descriptiva recopilada en el diario de clase, se ha procurado exponer de forma pormenorizada los factores controlantes clave a los efectos de ayudar a investigadores en futuros experimentos que incluyan materias afines. En la discusión se exponen dichos factores controlantes clave.

En lo que corresponde a aspectos de validación, y para poder establecer un análisis comparado bien fundamentado metodológicamente, la asignación de grupos experimental y de control ha seguido un determinado proceso que exponemos a continuación. Los alumnos han tenido que escoger un grupo de dos posibles, con horarios diferentes. A priori no conocieron qué grupo recibiría ABP por lo que la elección se debió fundamentalmente a preferencias personales condicionadas por horarios, interferencias con otras asignaturas, etc. Una vez cerradas las listas de alumnos por grupo, y de forma aleatoria con una moneda al aire se asignó el grupo experimental a ABP y el grupo de control a MET. Desde el punto de vista metodológico el experimento es de tipo cuasi-experimental con grupos experimental y de control independiente. Se ha añadido una prueba de homogeneidad de muestras lo que ha exigido un pretest, además del postest propio de la validación estadística. La pertenencia a cualquiera de los grupos ha exigido una asistencia mínima al 80% de las sesiones. El temario para ambos grupos fue el mismo, pero el grupo de control recibió únicamente MET mientras el grupo experimental recibió MET durante las 6 primeras semanas, y el resto del cuatrimestre ABP. No todos los alumnos han participado de los grupos objeto de evaluación, existiendo 3 alumnos –todos ellos repetidores de la asignatura- que no asistieron regularmente a clase, quedando eliminados de las pruebas correspondientes para evitar distorsiones en los resultados. El tamaño de cada grupo se fijó en 22 alumnos, siendo 44 en total los sujetos implicados en la investigación. El total de matriculados en la asignatura ha ascendido a 47 alumnos para el curso 2015-16, lo que ha permitido una implantación del ABP en el grupo experimental con la atención que requiere, dado que en grupos grandes esto no sería posible. Por tanto, un número reducido de alumnos, si bien reduce la significatividad estadística a efectos de extrapolación de resultados, permite implantar un verdadero ABP, en el sentido otorgado por Woods (2012) al mismo. El periodo común para los dos grupos de 6 semanas de MET comprendió la base de conocimientos sobre fundamentos hidráulicos, incluyendo sistemas de tuberías, bombas hidráulicas y conducción en lámina libre. Posteriormente se desglosaron las formas didácticas, siendo el ABP a partir de entonces aplicado al grupo experimental únicamente. El grupo de control continuó con el MET sin solución de continuidad temporal, incluyendo las aplicaciones de riego localizado, riego por aspersión, canales y acequias, depósitos y balsas de riego. Las obras de drenaje se impartieron en dos sesiones finales con MET, común para los dos grupos y no siendo objeto de evaluación. El grupo experimental ha requerido de un trabajo autónomo del estudiante importante para asimilar los bloques de materias que no han tenido dedicación directa en clase conforme a un MET. Dichas materias se encuentran en forma implícita en los diferentes casos prácticos analizados en las correspondientes sesiones de ABP siendo comentadas en la solución final dada por el tutor una vez resuelto el caso en cuestión, y a medida que éste se va desarrollando en clase, tal como hemos comentado en el apartado anterior de aplicación y puesta en práctica del ABP. Los fundamentos básicos del método cuasiexperimental aplicado al ámbito de la educación han tenido en cuenta los planteamientos y ejemplos de García Llamas, Pérez Juste y Río Sadornil, (2006).

Con respecto a la evaluación del ABP, se ha tenido en cuenta tanto aspectos de eficacia como de eficiencia, a veces confundidos y netamente diferentes. Según la Real Academia Española, eficacia es la "capacidad de lograr el efecto que se desea o se espera" y eficiencia la "capacidad de disponer de alguien o de algo para conseguir un efecto determinado". Dichos términos, aplicados al contexto de la investigación en cuestión, los explicamos como sigue: 1) entendemos por mayor eficacia de un tratamiento didáctico el que produce un mayor número de aprobados –en tanto que efecto esperado-para un mismo nivel de recursos implicados, y 2) por mayor eficiencia una mayor calificación media obtenida para un mismo nivel de recursos empleados, en tanto que capacidad para disponer de dichos recursos docentes. Un tratamiento docente, por tanto, será más eficaz que otro si proporciona mejores resultados de rendimiento académico. Pero además, dicho método docente con respecto a otro será más eficiente si dicha circunstancia se produce con un mejor aprovechamiento de los recursos docentes y esfuerzo de los alumnos implicados. Esta aclaración no agota la cuestión, que podría ser incluso de un debate independiente. Aun así, hemos considerado interesante precisar estas cuestiones que en lengua castellana dan lugar a confusión. En idioma inglés, la eficacia (effectiveness) y la eficiencia (efficiency) parecen seguir ámbitos del significado del lenguaje propios. Hemos formalizado la inclusión de esta discusión a través de las metas 1 (relativa a eficiencia) y 2 (relativa a eficacia), como objetivos secundarios subsumidos al principal de la investigación.

El instrumento de medición ha consistido en pruebas objetivas para evaluación de conocimientos similares para los grupos experimentales y de control. Para más información relativa a la herramienta en cuestión se pueden consultar los antecedentes de los autores. La técnica no paramétrica seleccionada para el contraste de hipótesis ha sido la prueba de la mediana, variante de la prueba χ^2. La técnica seleccionada es una técnica estadística robusta, adecuada al tamaño de la muestra y al tipo de datos con los que estamos trabajando con la precisión apuntada. El tamaño de los grupos impone técnicas no paramétricas para su análisis estadístico en cualquier caso. En cuanto a la selección concreta de la técnica en cuestión, el empleo de la técnica de la mediana está aconsejado en contrastes de hipótesis para estudios con diseño similar según las recomendaciones expuestas por autores solventes en la materia (García Llamas et al., 2006). El primer objetivo pragmático de un alumno de ingeniería posiblemente sea superar la asignatura en curso, independientemente de obtener una calificación elevada en primera instancia. El empleo del test de la mediana evita falsear algunas evaluaciones en las que pese a que se aprecien diferencias significativas entre los alumnos, puede resultar que las medianas se encuentran bajas, a veces incluso dentro del rango de suspenso. En ese caso no se podría hablar de éxito en la evaluación, pese a que existan diferencias significativas entre el grupo de control y experimental: obtener un 2 o un 4 de calificación implica una diferencia significativa entre ambos valores, pero no implica aprobar la asignatura. Por tanto se considera que los alumnos deben superar las pruebas objetivas en un porcentaje razonable para que el ABP sea considerado eficiente con respecto al MET. Por otra parte, dicho test de la mediana penaliza los valores que queden alejados de la mediana, afectando al valor de χ^2 empírico en forma notable.

Se han realizado un pretest en ambos grupos al efecto de comprobar si son comparables los grupos en cuestión. El test de homogeneidad de muestras, si bien no siempre es obligatorio al ser aleatoria la asignación a los grupos definidos, hemos considerado prudente realizarlo. Resultó que no existen diferencias significativas aplicando el test de la mediana al ser χ^2 teórico = 3,841 > 0,818 χ^2 empírico, para un nivel de confianza del 95%, con lo cual han podido ser comparables los grupos definidos. Se estableció, tanto para el pretest como para el postest una cláusula ceteris paribus para toda la investigación empírica. En este sentido, la variable dependiente es el rendimiento académico y la independiente el tratamiento mediante ABP o MET. Formalmente: haber sido o no sujeto sometido a tratamiento (ABP en nuestro caso) es la variable independiente. En la evaluación, la hipótesis a falsar o verificar es "el tratamiento dado mediante ABP no afecta al rendimiento académico". A estas dos variables, se les añade la cláusula ceteris paribus en cuestión, por lo que todo lo demás debe teóricamente permanecer igual si se quiere hacer un experimento conforme al método científico aplicado a un entorno social-educativo. En la práctica hay variables extrañas de difícil cuantificación, habiéndose detectado y registrado en el correspondiente diario de clase las siguientes: 1) horario de las clases variable por cada grupo y 2) interferencia de festividades para cada grupo diferente, pues no han tenido siempre los mismos días de clase. Razones operativas –imposición del Centro responsable las aulas y disponibilidad temporal de los docentes implicados- han hecho imposible controlar las variables extrañas mencionadas. No obstante, se han adoptado las siguientes medidas para que su interferencia haya sido la menor posible: 1) el pretest y postest lo han efectuado los grupos experimental y de control a la vez y en la misma aula; y 2) ambos grupos, experimental y de control, han efectuado pruebas similares. Además, la corrección de exámenes ha sido triangulada por otro profesor con docencia en el área sin docencia en los grupos GE y GC. Por último, los resultados finales han sido validados mediante un juicio de experto proporcionado por el profesor de más antigüedad con docencia en el área, sin docencia en GE y GC, y distinto del profesor que triangula la corrección de exámenes.

RESULTADOS Y DISCUSIÓN

A continuación se exponen los resultados y discusión correspondiente, tanto de los resultados cuantitativos resultantes de la validación estadística, como cualitativos referentes a aspectos de contexto detectados en el diario de clase. Tenemos:

Validación estadística

Para comprobar si existe una mejora significativa del rendimiento académico una vez recibido un tratamiento mediante ABP, se hicieron las pruebas de control (pretest y postest) y se obtuvieron las siguientes calificaciones mostradas en la tabla 1.

Tabla 1. Resultados de la prueba de control de conocimientos por grupos.

Pretest				Postest			
Grupo de control		Grupo experimental		Grupo de control		Grupo experimental	
1,5	3,7	1,0	4,0	3,0	5,0	3,0	6,8
2,2	3,8	2,0	4,0	3,0	5,2	3,3	7,0
2,2	4,0	2,4	4,2	3,3	5,7	4,0	7,0
2,4	4,0	2,4	4,3	3,5	6,0	4,7	7,2
2,5	4,2	2,8	4,5	3,5	6,0	5,0	7,4
2,7	4,2	3,0	4,6	3,8	6,2	5,5	7,7
3,0	4,5	3,0	5,0	4,0	6,5	5,8	7,8
3,0	4,5	3,2	5,0	4,0	7,0	6,0	8,0
3,2	5,0	3,3	5,0	4,5	7,5	6,2	8,2
3,4	5,0	4,0	5,5	5,0	7,7	6,5	8,5
3,5	5,7	4,0	5,7	5,0	8,0	6,8	8,6

Nota: Orden acorde al test de la mediana.

A estos resultados se les aplicó la técnica no paramétrica del test de la mediana comentado, debido al reducido tamaño de las muestras (inferiores cada grupo a 50 alumnos). Los puntos formales que definen la prueba efectuada son: 1) diseño cuasiexperimental, de dos grupos independientes, con una variable independiente y muestras pequeñas (n < 30); 2) nivel de medida ordinal; 3) hipótesis bilateral: a) H_0: no existen diferencias entre ambos grupos y b) H_1: existen diferencias significativas; 4) contraste no paramétrico. Prueba de la mediana, puesto que la medida empleada hace referencia a dos únicos rangos o categorías: por encima o por debajo de la mediana o lugar central de todas las puntuaciones y 5) pasos: a) obtención de la mediana de todas las puntuaciones. Md = 6,0 b) obtención de un χ^2 teórico para un nivel de confianza del 95% y 1 grado de libertad (χ^2 teórico = 3,841) y c) obtención de un χ^2 empírico mediante la siguiente expresión (1) que relaciona las frecuencias observadas f_o y las frecuencias esperadas f_e:

$$\chi^2 = \sum_{g=1}^{G} \sum_{c=1}^{C} \frac{(|f_o - f_e| - 0,5)^2}{f_e}$$

Se comprobó que al ser χ^2 teórico = 3,841 < 4,492 χ^2 empírico, hay diferencias significativas entre ambos grupos, a nivel de postest y para un nivel de confianza del 95%. Por tanto, se rechaza entonces la hipótesis nula (H_0) y se acepta la hipótesis alternativa (H_1): existen diferencias significativas en el rendimiento académico de los alumnos de Ingeniería del Riego que han recibido un ABP frente a los que han recibido un MET. Pero además, y quizás más importante que la mera validación del test de la mediana están los datos relativos a superación (o no) de la prueba objetiva. De esta forma, el porcentaje de aprobados ha sido del 59% y 82% respectivamente para los grupos de control y experimental (Figura 2).

De los datos anteriores se deriva la nota media en ambos grupos, habiendo sido de 5,2 en el grupo de control y 6,4 en el grupo experimental. Las desviaciones típicas han sido a su vez de 1,56 y 1,61 respectivamente. La variabilidad expresada por las desviaciones típicas es pequeña. En el nivel de conocimientos actual y con los datos disponibles, se puede deducir una mejora en el rendimiento académico del grupo que recibió ABP frente al grupo que recibió únicamente MET. Además del rendimiento académico hay otros aspectos que previsiblemente hayan mejorado, sin ser el experimento en su vertiente cuantitativa suficiente para poder evaluarlos.

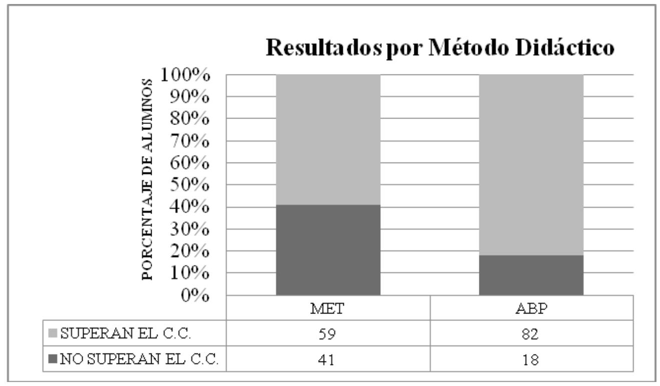

Fig. 2. Resultados porcentuales agregados comparados.

Información de contexto derivada del diario de clase

El diario de clase se ha configurado como una herramienta muy interesante para proporcionar ciertas informaciones que no han sido detectadas por la validación estadística. El diario de clase se ha llevado al día siguiendo los postulados de Hammersley y Atkinson (1994), tal como comentamos con anterioridad. No ha habido dificultades especiales en el seguimiento del diario, más allá de la laboriosidad e ingente cantidad de trabajo que conlleva. No entraremos en los detalles de la gestión del diario de clase, cuyo fundamento metodológico los lectores podrán encontrar en la referencia citada. Tan solo mencionar que la información descriptiva que se va recopilando muy paulatinamente, no muestra indicios hasta bien avanzado el curso. Por tanto, es una vez culminado el trabajo de campo mediante observación participante y registro de la información descriptiva cuando realmente se pueden obtener informaciones relevantes. Las informaciones de contexto, que en síntesis hemos denominado *contexto situacional*, y que pudieran parecer triviales (climatología local con bajas temperaturas o lluvias en invierno, ambiente en el aula en la cercanía de festividades, mal ambiente social después de un infructuoso trabajo de la selección de futbol nacional la noche anterior, etc.) se han revelado como aspectos influyentes en la buena marcha de las sesiones ABP. Por tanto, los factores contextuales influyen en el ánimo de las sesiones de ABP con mayor intensidad que en las del MET. En efecto, si el ambiente en el aula no es el más adecuado, las sesiones de ABP con una participación activa de los alumnos se verá resentida. Esto no se da igual en una sesión expositiva siguiendo un MET dado que, en estos casos, el alumno tan sólo tiene que sentarse y recibir la clase correspondiente –con mejor o peor humor-. Factores contextuales que pueden afectar, de los que ya han sido mencionados algunos, el que quizás supone mayor implicación es la cercanía a fiestas populares importantes, pues han conllevado una distracción de las mentes hacia un futuro lúdico inmediato.

Además de este factor contextual mencionado, podemos añadir que existen dificultades adicionales a la Ingeniería del Riego como asignatura a impartir, que no se presentan en otras materias. Algunos estudiantes han mostrado cierto rechazo con respecto a la hidráulica, si bien existe atracción hacia las aplicaciones del riego. A su vez hay carencias formativas en Física, lo que se traduce en dificultades para captar los conceptos de fundamentos hidráulicos requeridos. Otras materias, como por ejemplo Construcciones Agrarias muestran cierta simpatía por el deseo de conocer materias de construcción, y por tanto, la implantación del ABP ha sido más fácil.

En cuanto a la adquisición de competencias, recogidas en la guía docente de la asignatura, no se pueden evaluar todas por las pruebas objetivas. Estas competencias, que comprenden tanto específicas como transversales, se desarrollan sin una delimitación neta en cada metodología docente. El desarrollo del ABP incide especialmente en 1) la capacidad para conocer, comprender y utilizar los principios de toma de decisiones mediante el uso de los recursos disponibles para el trabajo en grupos multidisciplinares, 2) que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado, 3) capacidad para la resolución de problemas, 4) capacidad de aplicar los conocimientos en la práctica, 5) capacidad para trabajar en equipo, 6) creatividad y espíritu inventivo en la resolución de problemas científico-técnicos y 7) capacidad de gestión de la información en la solución de situaciones problemáticas; mientras que el MET afecta sobre todo a 1) capacidad para conocer, comprender y utilizar los principios de ingeniería del medio rural: cálculo de estructuras y construcción, hidráulica, motores y máquinas, electrotecnia, proyectos técnicos, 2) que los estudiantes sepan aplicar sus conocimientos a su trabajo o vocación de una forma profesional y posean las competencias que suelen demostrarse por medio de la elaboración y defensa de argumentos y la resolución de problemas dentro de su área de estudio, 3) Que los estudiantes tengan la capacidad de reunir e interpretar datos relevantes (normalmente dentro de su área de estudio) para emitir juicios que incluyan una reflexión sobre temas relevantes de índole social, científica o ética; y en diferente grado al resto de competencias. El postest, como prueba objetiva tras recibir el tratamiento docente (ABP o MET), incidirá especialmente en la capacidad para la resolución de problemas. En cualquier caso debemos cuidarnos de entender esta evaluación de competencias como campos netamente definidos.

Tenemos que hacer una referencia en esta discusión al trabajo autónomo del estudiante. El trabajo autónomo del estudiante se revela fundamental en la aplicación del ABP para la materia Ingeniería del Riego. Las carencias en Ciencias Físicas, fundamentales, han obligado a preparar unos apuntes específicos, los cuales están a disposición de los alumnos en la plataforma virtual. Una colección de problemas resueltos se acompaña al material teórico para servir de ayuda. No se concibe un exitoso ABP sin un trabajo autónomo del estudiante, tanto para el fundamento hidráulico, como para el estudio en privado de aquellos temas que, por razón de la metodología ABP, no serán objeto de exposición conforme a un MET. El profesor debe dar toda la información en soporte adecuado para facilitar dicha tarea al alumnado.

Por último, para culminar esta discusión, añadimos una información adicional obtenida tras la revisión y comparación de las pruebas objetivas efectuadas en el pretest y el postest, tanto en GC como GE. Resulta que tras la revisión de las pruebas objetivas, se comprueba que se produce una mejora en los planteamientos para la resolución de los problemas en alumnos que han seguido un ABP. La secuencia de razonamiento lógico seguida en la resolución de los problemas por alumnos que han seguido un ABP presenta, en general, unas pautas más acordes con el método científico. A su vez, se han reducido los errores de cálculo en los alumnos que han seguido un ABP derivados de operaciones matemáticas incorrectas o de manejo equivocado de la calculadora. Creemos que ello se debe al entrenamiento que proporciona el ABP.

CONCLUSIONES

Existen diferencias significativas en los aprendizajes en Ingeniería del Riego entre alumnos que han participado en un programa de enseñanza basada en un ABP, y otros alumnos que han participado en un programa de aprendizaje siguiendo un MET y de realización de problemas por el docente; Se produce mejora en los planteamientos para la resolución de los problemas en alumnos que han seguido un ABP; el ABP se configura como un método didáctico eficaz, y a su vez, más eficiente que el MET combinado con el de realización de problemas por el docente; Se han reducido los errores de cálculo en los alumnos que han seguido un ABP; El contexto situacional afecta a la buena marcha de las sesiones ABP.

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Received 9-05-2016 /Approved 15-05-2017

Teaching models and learning experimenting with chemistry: possibilities to promote Brazilian youngster and adult's learning with meaning

Modelos de enseñanza y aprendizaje de la química: posibilidades de promover el aprendizaje significativo del joven y del adulto

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Abstract

This paper reports a teaching intervention developed for promoting chemistry learning of 1st year of medium education at the Youngster and Adult Education Center (YAEC), in the city of Barra do Bugres, state of Mato Grosso, mid-western Brazil. The research involved 21 women at YAEC. The research methodology adopted is qualitative, allowing us to analyze the results subjectively and interpretatively. The data gathering instruments were one questionnaire applied before and after performing the course activities, as well as observations recorded in a logbook developed by the students. The results were analyzed through a content analysis technique. The categories of analysis were: youngster and adult's levels of interest, meaning and transposition of the chemistry knowledge for the resolution of problem situations. The study allowed us to identify and develop teaching strategies that would make possible contextualized chemistry teaching.

Key words: *youngster and adult education, teaching and learning of chemistry, teaching intervention.*

Resumen

El siguiente artículo narra una intervención educativa desarrollada para promover el aprendizaje en química en el 1er. año de secundaria, en el Centro de Educación de Jóvenes y Adultos, en la ciudad de Barra do Bugres, Estado de Mato Grosso, Centro-oeste de Brasil. En la investigación participaron 21 mujeres del CEJA. La metodología de investigación adoptada ha sido la cualitativa, permitiendo analizar e interpretar subjetivamente los resultados obtenidos. Los instrumentos utilizados para la recolección de datos fueron: un cuestionario, aplicado antes y después de la realización de las actividades y las observaciones registradas en un diario. Los resultados han sido evaluados por medio de la técnica de análisis de contenido. Las categorías analizadas fueron: interés, significación y transferencia de los conocimientos estudiados para la resolución de situaciones problema. El estudio ha permitido identificar y desarrollar estrategias didácticas que posibilitan una enseñanza de química contextualizada.

Palabras clave: *educación de jóvenes y adultos, aprendizaje en química, intervención didáctica*

INTRODUCTION

Chemistry is a subject that involves scientific abstract concepts which are sometimes difficult for students to understand and learn (Chassot, 1993). Chemistry is the science that studies matter, its physical-chemical transformations and energy variation that occur during those processes. It represents a major portion of all natural, basic and applied sciences. Thus, it is important that educators encourage the perception of daily, observable, measurable situations, since the concepts that are brought into the classroom, according to Freire (1996), originates from their reading of the world, where the meanings are pertinent to them.

The structure of matter, the properties of chemical compounds and the articulating of these scientific concepts with the natural phenomena and technological advances of societies should be developed in schools (Coringa; Pintel; Ozaki, 2007). Consequently, it is important to develop innovative teaching and learning strategies to stimulate students' interest, reasoning and understanding of Chemistry concepts. Chemistry teaching should play an important role of retrieving, in a dialogical fashion, the different meanings attributed to Chemistry knowledge within a physical and social reality (Chassot, 2011).

Chemistry is interlinked with other sciences (e.g. Biology and Geology) and is present in citizens' daily routine, for instances, production and conservation of food. Towards that sense, the Brazilian National Curricular Parameters (BNCP) (Brasil, 2000) recommends that teaching practice should focus on the development of students' competences through significant and contextualized knowledge of science. Also, the Curricular Instructions for the Brazilian Medium Education Nature Sciences Area (SEDUC/MT, 2010) indicate that the construction of Chemical knowledge should be established by means of problematic and challenging situations to students.

Chemistry daily routine should lead to an understanding of the social and economic relations in society (Luft, 1988). Students' daily knowledge is constructed by adult men, who convey it successive generations, making it a part of the culture (Lopes, 1999). Towards that sense, relating 'scientific knowledge' with 'daily knowledge' requires a significant intermediation through education.

Chemistry is a scientific area that allows us to understand how nature, its rules and its interactions relate with society. Students need to develop competences which allow performance of many jobs (e.g. Medicine, Chemical Engineering). Nevertheless, the most relevant weaknesses in traditional curriculum of chemistry are: a lot of new scientific concepts; social, industrial and ecological outdated problems; the ways and methodology of teaching modern chemistry are not contemplated (Orlik, 2002, 2013).

According to a Science-Technology-Society (STS) perspective of science education, the scientific concepts that are brought into the classroom should emerge from students' interpretation of the world (Santos, 2012; Bazzo, 2012; Mansour, 2009; Vieira, Tenreiro-Vieira, & Martins, 2011). Thus, under this constructivist perspective, experimental activities should be organized taking into consideration students' previous knowledge about scientific concepts (Giordan, 1999). This way, dialog between teacher and students take on an important role in classroom. This approach for Chemical education is, thus, aligned with international recommendations of scientific community of science education (Cachapuz, Lopes, Paixão, Praia, Guerra, 2004).

The Salters' Chemistry has been developed, covering biology, chemistry, and physics for the high school age range (11–18 years) in England and Wales. Salters' describes the development and key features of one of the major context-based courses for high school students (Bennett & Lubben, 2006). However, when employing experimental activities in classroom, care should be taken for our classes not to become soaked in positivist thinking. Its fundamental characteristic consists on founding all knowledge on sensory data and stating that only probable relations may be established between things that are likely to be confirmed through repeated observations, without the certainty that they are universal or necessary (Del Pino, 2013).

Contemporary positivism stands on Comte Positivism from the 19th Century. Comte restricted scientific ambitions to pure and simple description of phenomena and relegated to the domain of metaphysics any attempt on the primary causes. The true positivist conception in science starts from the fact it deems neutral and primordial, that observation is the only material from which science is constituted and should develop. Whether a statement is true or false may only be established by resorting to experience, testable by the senses, that allows perception of reality (Del Pino, 2013).

This study was related to the development of a teaching proposal on 'food' involving Youngster and Adult Education students (up to 18 years old) from a public school in the interior of Mato Grosso state, in the mid-western region of Brazil. The teaching proposal was aligned with the national curricular base of knowledge in Chemistry, and in consonance with the history of Chemistry science development. The teaching proposal included conceptual aspects that allow for the students' understanding of the constitution, properties and transformation of materials, with their models explained and highlighting the social implications related to their production and use (SEDUC/MT, 2010).

The main aim of this study was to evaluate whether the teaching and learning proposal contributed (or not) to youngster and adults' Chemistry learning.

THE STUDY

Outline of the intervention

This study was developed during the third school trimester of 2013 (from October to December month) with a class from the 1st year of Medium Education at the Youngster and Adult Education Center, in the city of Barra do Bugres, state of Mato Grosso, mid-western Brazil. The participants were 21 students, all female, with ages between 18 and 46 years old. Among them, 6 students perform operational activities in different services (e.g. sugar mill, refrigerating plant construction, civil construction, commerce), and the other ones were housewives (some of them make handicrafts to complement their family income). Their time out of school varied between 2 and 25 years.

The theme "Food" was chosen for Chemical education course, as it is believed to be a potentially meaningful subject for these students' social context. The teaching methodology employed during classes was from a constructivist perspective (Coll, Martin & Mauri, 2006), with a STS approach (Santos, 2012; Bazzo, 2012; Mansour, 2009; Vieira, Tenreiro-Vieira & Martins, 2011).

These STS approach was integrated in the proposal developed in the following indicators: A) Explores the chemistry topics as a function of their social usefulness; B) Presents situations for daily routine application, for new knowledge, where STS interaction is present at the end of the proposed activities; C) Presents proposals that lead to student involvement in projects that promote critical thinking skills about issues where STS interaction is manifested; D) Proposes diversified activities for reality simulation that has students place themselves in others' places, solve problems, carry out debates, discussions, research about issues where STS interaction is manifested and the explicit appeal of critical thinking skills.

Adapting Santos (2008) approach to Chemical teacher action, the following activities were designed and implemented by the researcher of this study, who was also the teacher of this course: i) give sense to the content (setting off from the contextual and emotional meaning); ii) specify (after contextualization, lead to the perception of specific characteristics); iii) understand (concept construction and use in several contexts); iv) define (clarify a concept); v) argument (spoken, written, verbal and non-verbal text); vi) discuss (reasoning and arguing); and vii) bring it to life (intervention in reality). Table 1 presents the main topics that were selected for discussion in the course.

The course involved discussions between the teacher/researcher and the students about the 'atomic models', a theme that was covered under the topic "Voyage into food: from macro to micro". To work on the structure of the matter, a questioning methodology was implemented. The initial motivation for the development of studies about Chemical Elements was the question: "What constitutes foods?" The following questions emerged during the discussions between the teacher and students about this theme: 1) What constitutes the materials? 2) How are the substances that surround us formed? 3) What is the name of these parts that make up a whole? 4) What is the meaning of atom, and is it still valid? 5) What charges do atoms feature? 6) Where are they located?

For the 'atomic model evolution time line exposure', the following experimental activities were proposed: A jar completely filled with jaboticabas (large, purple berry) represented 'Dalton's model' for the constitution of matter. The students were requested to remove all the jaboticabas from the jar and put them back in to understand the model proposed by that scientist.

To understand 'Thompson's model', chopping paper and rubbing a plastic pen on their scalps was proposed. Once the phenomenon was observed, it was explained that the rubbing caused the electric charges to dislocate, after that, the attraction of the pieces of paper by the pen material, which at that moment would be electrically charged.

For the 'Rutherford-Bohr atomic model', the proposal was to represent the atom using plates, eggs and pieces of paper to identify the electrosphere and nucleus, and where the protons, electrons and neutrons are located.

Table 1. Curricular proposal developed for Youngster and Adult Education (YAE)

Teaching models	Topics covered	Related contents	STS indicators
Assembly of the food pyramid with daily foods.	The importance of food, their origins and main characteristics.	Concept of food and its origins; Study of materials; Pure and mixed substances; Food Groups and Food Pyramid.	A, B
Separation of the foods used in the food pyramid into two groups: animal and vegetable origin.	Diet and caloric value of food.	Food classification; Balanced food diet; Food wheel; Caloric value of food; and Benefits from a healthy diet.	A, C, D
Activity to demonstrate hand sanitization using water soluble dyed ink instead of detergent.	Good practices in food preparation.	Good practices in preparation; Hygiene; Types of contamination; Contaminating agents, Preparation of solutions and vitamins.	A, B, D
Assessment of each student's fridge pictures including a discussion to identify what is correct and incorrect when organizing the fridge.	Food conservation through refrigeration: organizing the fridge.	Food conservation; Correct way of storing food; Packaging; Characteristics and validity; Conserving with cold and thermal convection.	A, D
Preparation of stuffed chocolate bonbons for selling.	Food processing and trade.	Food processing; Changes in physical states; Product appearance and aesthetics; Production standardization.	A, B
Press release about bovine milk tampering by adding Hydrogen peroxide and practical activity about the substances basic acid character.	Chemical reactions that occur in food	Types of chemical reactions; Evidence of the occurrence of a reaction; Identification of reagents and products; Indicators, catalysts and reaction medium; Enzyme inhibition.	A, D
Visit a water treatment plant.	Water as a substance and the process of making it potable	Functions of water in the body and in food preparation; Water treatment and potability; Processes of blend separation; and Chemical analyses for quality control.	A, B
Construction of cellular models with foods.	The relation between nutrients and cell composition.	Organic and inorganic cell molecules; Chemical composition of cells; Prokaryote and eukaryote cells; Organells and their functions; Animal cells and Vegetable cells	A, C
Elaboration of the periodic table with foods.	Chemical composition of food	Mineral salts; Chemical elements; Percentage of elements that make up the human body and food; and Periodic Table of elements.	A, C
Jar with jaboticaba fruit: Dalton's model; a plate with a raw egg and pieces of paper with the + and - signs representing protons and electrons.	Voyage into food: from macro to micro.	Material structure and organization; Dalton's, Thomson's and Rutherford-Bohr's atomic models; Electrosphere and nucleus; Protons, electrons and neutrons.	A, D

The electrons were represented by minus signs (-) in red, laid out on the egg white, representing the empty electrosphere. The protons, in turn, were symbolized by plus signs (+) in blue, laid out on the yolk, representing the solid atom nucleus. The neutrons were also added to the yolk and were represented by the color orange, as they are located in the nucleus. The result was surprising, as can be observed in Figure 1.

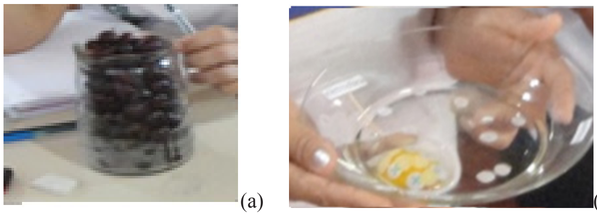

Figure 1. Dalton (a) and Rutherford (b) atomic model

From the experiments with jaboticabas in the jar, chopped paper attracted by the electrified pen through friction on the scalp and the representation of the atomic regions and charges with eggs, it was possible to provide a view of an invisible world (Chassot, 2011).

METHODOLOGY

This study is characterized as research-action method, which according to Thiollent (1985), is an empirical research performed through planned actions and in which everyone, researchers and participants get involved cooperatively. Research-action is understood as being where the investigator interacts in a different manner with the investigated individuals aiming at a planned action in the face of the problems identified (Coutinho, 2011).

The methodological approach of the research is qualitative allowing us to analyze subjectively and interpretatively the results obtained. Lüdke & André (2013) advocate that the qualitative aspects allow understanding the intricate aspects that occurs within a micro social situation, by placing the researcher in the middle of the research scene to, then, take a position about the results obtained. Table 2 presents the participants, the data collection and analysis instruments used in this study:

Table 2 – Participants, data collection and analysis.

Participants	Data collection	Course development			Data analysis
		Beginning	During	End	
21 students	questionnaire 1	x			Content analysis
	questionnaire 2	x		x	
	Logbook of activities developed by students		x		
	questionnaire 3			x	

Questionnaire 1 had the following aims: to characterize the sociocultural and economic profile of the participants. Questionnaire 2 was applied twice, at the beginning and at the end of the course. The aims of this instrument were: to identify previous knowledge of participants about the theme of the course (pre-conceptions…); and to evaluate and compare the participants' learning developed in the classroom concerning the concepts of the course. The logbook notes served to describe the actions developed the course. Questionnaire 3 was applied at the end of the course in order to evaluate the teachers' pedagogical practice effectiveness. This questionnaire had five questions: How do you evaluate the chemistry lessons this semester? What did you enjoy or learn during the chemistry lessons? What could be improved in next chemistry courses? What should be continued? What were the contributions for your daily life?

All students involved in the research signed 'Consent Forms' and committed themselves to voluntarily take part in the proposed activities and authorized the use of the data, including the use of images. To ensure the anonymity of the participants, their names have been replaced by S1 (Student 1), S2, (Student 2), and so forth.

Data collected were analyzed using content analysis technique (Bardin, 2015). Bardin (2015) defines Content Analysis as: "a set of communications analysis techniques that employs systematic, objective procedures to describe the message contents" (p. 38). This technique seeks to learn the message that hides behind words and reveal other realities the messages contain. Data analysis aimed to understand the positive and negative aspects in the execution of the course, as well as to identify which contributions and learning EXPERIENCES were observed in this group of students before and after the development of the pedagogical practice.

RESULTS AND DISCUSSION

Discussion took place under the light of the theoretical/conceptual referential, constructed from different bibliographical sources referenced herein.

Students' perceptions about their learning during the course:

Data collected through the questionnaire allowed analysis of students' interest and/or willingness to learn Chemistry. Figure 2 illustrates this category results.

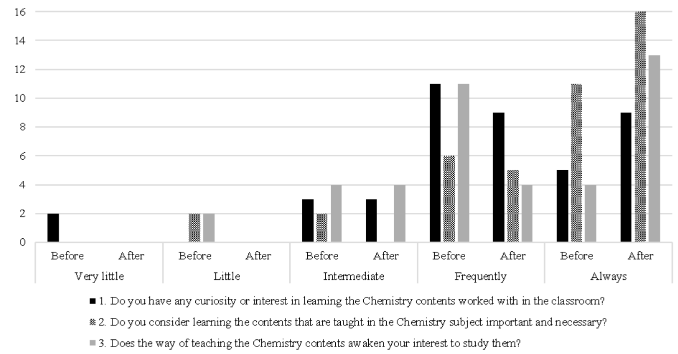

Figure 2 - Answers from students to questions 1, 2 and 3, listed under the "interest" category.

Upon questioning whether students feel curiosity and interest to learn the Chemistry contents worked with in the classroom (question 1), the data reveal that the subject contents are interesting and intensify when worked with in a contextualized fashion. These data corroborate what Santos (2008) thinks about how important interest and motivation are as a driving force to activate the learner's cognitive structures. Also clear is the requirement to create the conditions for that initial individual's impulse translates into a will to learn the contents. Furthermore, it is worth remembering that the interest contributes to students' attention in the study object.

In question 2, the answer "Always" had the most significant increase. This increase in how important learning Chemistry is also associated with the motivational factor, since the latter is an impulse towards pursuing to meet a need (Santos, 2008). Question 3 raises the issue of whether the way of teaching was stimulating, motivating, and whether it had any influence in learning the content. We point out the fact of a high rate of interviewees changing their options from "Frequently", which went down from 11 to 4 answers, to "Always", which went up from 4 to 13 answers. It can be perceived, from the data obtained, that the teaching methodology has an influence in learning. This reveals that a differentiated teaching methodology has an influence in the development of classes. As Santos (2008) states, motivation may be activated by internal factors (needs, interest) and external ones, such as encouragement and incentives. This characteristic reinforces Freire's (1996) idea that simply reproducing lessons is not enough, but creating teaching situations that allow for the production/construction of knowledge. It also shows that the teaching methodology may benefit from exciting and diversified strategies at the right moment (Antunes, 2001).

The second predefined category for analysis refers to students' meaningfulness about…. Questions 4 and 5 seek to asses this aspect. Figure 3 illustrates this category results.

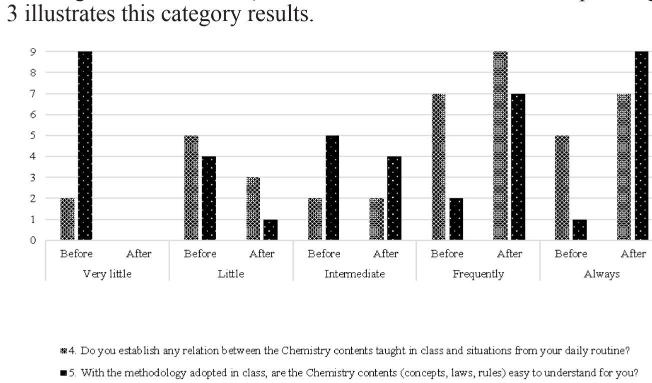

Figure 3 - Answers from students to questions 4 and 5, listed under the "meaningful" category.

From the answers to question 4 it can be perceived that there was an increase among the students who considered such content meaningful and relate them not with compulsory study items, but as something relevant for their lives. Working with "food" allowed us to establish relations between the school contents and daily situations. This finding corroborates Ausubel's (1982) theory when advocating that the logical meaning of the study material is transformed into a psychological meaning for the student throughout meaningful learning situations.

From the data assessed in question 5, it can be seen that most interviewees improved their understanding where Chemistry studying is concerned. Such a finding serves to confirm the teachers' mediator role in the dialectic conception, where the interaction between teacher/students/content occurs, oscillating between actions, reflection and action. It is also perceived that, in order to attribute meaning or understand certain content, the cognitive level must be mobilized so that the pre-existing knowledge schematics serve as a support for the new learning (Coll, Martin & Mauri, 2006; Antunes, 2001).

In question 6 that covers where chemistry exists, 3 students thought Chemistry would be present in the books and in classroom, that is, they were harnessed to the traditional thinking of the bench school that Freire (1983) criticized for not managing to establish any relation between school knowledge and their daily lives. This was one student's option after applying the teaching proposal. There was an increase in the number of students who deemed chemistry contents meaningful, as something relevant for their lives. Working with "food" allowed us to establish relations between the school contents and daily situations. The meaning of the contents studied in Chemistry is harnessed to their establishment with the daily routine, which corresponds to one of the conditions for meaningful learning to take place, as defined by Ausubel (1982): the contents being considered as potentially meaningful for the learner.

The third predefined analysis category referred to the transposition of the knowledge studied to solve problem situations. Questions 7, 8 and 9 consider such category for analysis. Table 3 shows the results from this analysis category.

Table 3 - Students answers to questions 7, 8 and 9 related to the third category.

	Correct	
Question	**Before**	**After**
7. What processes are required to separate a blend containing sand, salt and iron filings?	6	10
8. Sucrose (C12H22O11), known as table sugar, is an important carbohydrate that comprises our diet. Soda pop contains phosphoric acid; whose chemical formula is H3PO4. By analyzing the formulas of those foods, which alternative correctly presents the chemical elements present in these substances?	8	19
9. Heartburn is caused by a high concentration of hydrochloric acid in the stomach. From the substances below, which one would be capable of neutralizing stomach acidity?	9	18

In question 7, we found that less than half of the class answered correctly the processes required to separate the blend of substances presented. However, we found that there was an increase from 6 to 10 when compared to the data from before the intervention. This finding reinforces the idea that a problem situation may only be solved when it meets the intellectual development and knowledge level of the students (Brasil, 2000). We chose to ask about something different from the issue being studied to corroborate the conceptual difficulty in the area of chemistry and that further encouragement is required for learning of that knowledge to occur in future studies.

To answer question 8, students had to apply all the knowledge constructed throughout the pedagogical practice in problem situations. It was noticed that meaningfulness of the contents studied occurred, since the number of correct answers regarding the knowledge of the Chemical Elements and use of the Periodic Table increased significantly, from 8 to 19 students. In a similar fashion to the studies of Branca (1997), there was a transposition of the learned knowledge in solving this specific problem. Once the referred proposal was applied, it was possible to develop cognitive frameworks necessary to solve such situation, which increased the rates of correct answers.

Question 9 brought the transposition of the knowledge constructed to solving life problems. The rate of correct answers in this question was impressive (it doubled). This shows that there was a development in the ability to identify/recognize the objects from the constructed learning and that the differentiated proposal followed the fundamental principles of YAE as stated by Kalman (2004): contextualization, the starting point being what the students already know and the heterogeneity of those involved.

Table 4 shows the categories and subcategories that arose from the material collected during the development of this teaching practice, particularly the analysis of the responses to the questionnaire 3.

Table 4 – Evaluation of the teachers' pedagogical practice effectiveness

Categories	Subcategories
Difficulties that CEJA "15 de outubro" students presented while studying Chemistry.	Difficulty understanding the teacher's explanation; Content complexity; Not understanding the formulas or calculations involved.
Student's assessment of the teaching proposal.	Favoring learning; The theme made understanding easier; It covered interesting things.
Aspects deemed most significant in the study.	The experiments performed; The contents developed; The practices with daily elements.
Suggestions for changes to future practices.	The teacher be more patient; Improve the physical structure of the school.
Contributions from the pedagogical practice experienced.	Learning for life; Changes to daily practices.

The gathered data were analyzed to gain support from theoretical references that discuss the teaching and learning processes, STS approach and meaningful learning. During the analysis, some authors who have been mentioned on the research were revisited. Results revealed how significant the pedagogical intervention was while studying Chemistry through foods.

To assess how much of the proposal was assimilated by the students, they were requested to write down in their logbook what learning was made possible from the development of the activity. Ausubel (2003) believes that assimilation involves a particular type of meaningful learning process that is closely linked to the main theses in the constructivist conception. Below is the transcription of answers from two students:

> *"I learned many things, for example, one experiment with magnetic attraction from a pencil, piece of paper and the scalp e rub on the pieces of paper and it sticks because it is a magnetic attraction. And the egg experiment, the yolk representing the nucleus that contains protons and neutrons, with the white being the electrosphere with a negative charge, the electrons. I found it was very interesting, a learning experience that I will keep for the rest of my life, it was a great experiment, like those in other days" (S6).*

> *"I learned a lot in Chemistry class, because I used to think that Chemistry was only about medicines, but the teacher taught us that we use it in everything we do, what we eat, drink and do has chemistry" (S17).*

The results also indicate that learning with meaning occurred, it being a process through which new knowledge pertaining to this stage in schooling relate to the pre-existing cognitive framework of the learners (Ausubel, 1982).

CONCLUSIONS

The study allowed identifying and developing teaching and learning strategies that would make possible an involving Chemistry teaching. It can be observed that there were countless advantages linked to contextualization in chemistry teaching: greater involvement of students, incentive to research, establishment of relations between chemistry and daily routine, exchange of experiences, interaction of the participants in the development of the activities, better understanding of the chemical concepts and the construction of learning for life.

The exchange of experiences that occurred during the development of the activities served to emphasize the social importance of each citizen in the pursuit of life quality. It also showed that shared knowledge is a means of social transformation, as it served to modify the reality of those who experienced it.

The use of concrete materials contributed to the understanding of chemistry concepts, which oftentimes are abstract. Socialization of more meaningful learning to elaborate conceptual maps showed that the proposed actions allowed for a wealthier conceptual construction. The chosen referential, i.e., planning of activities, strategies and resources employed assisted for the success of this educational process. This differentiated teaching methodology is positive for Youngster and Adult Education by providing for meaningful learning.

We believe that Chemistry teaching through 'food topics', as presented in chart 1, could be a possibility to promote Scientific Literacy of Youngster and Adult Education. Results showed that there was an increase in motivation and interest of students during the course, as well as the knowledge construction for solving practical problem situations. This way of action is to bet on Chemistry teaching not as a fragmented subject, but as teaching that seeks for solutions to the problems of this natural world.

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Received 24-06-2016 /Approved 15-05-2017

Falling temperatures: a simple estimation of the absolute zero

Bajando las temperaturas: una estimación simple del cero absoluto

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Abstract

When teaching an introductory course on thermal physics, one of the important challenges that a college physics teacher faces is to introduce to his/her students to the idea of an absolute minimum for the temperature, the so called 'absolute zero'. Indeed, given that the experiments used to determine the absolute zero temperature are usually performed in advanced thermodynamics courses, the usual procedure in introductory levels consists of passing on the notion based on the authority of a textbook. The aim of this article is to present a straightforward and low-cost experiment that allows introducing the notion of an absolute minimum temperature. The values obtained for the minimum temperature are in excellent agreement with the actual value of -273.15°C.

Key words: *absolute zero, school-level experiment, ideal gas.*

Resumen

Uno de los grandes desafíos que enfrenta un profesor de física de pregrado que imparte un primer curso de física térmica, es introducir a sus estudiantes en la idea que existe un valor mínimo para la temperatura, el denominado cero absoluto. En efecto, dado que los experimentos para determinar el cero absoluto suelen realizarse en cursos avanzados de termodinámica, el procedimiento habitual en los niveles introductorios consiste en transmitir la noción de temperatura mínima apelando a la autoridad de un texto. El objetivo de este artículo es presentar un experimento simple y de bajo costo que permite introducir la noción de temperatura mínima. Los valores encontrados para esta temperatura se encuentran en excelente acuerdo con el valor aceptado de -273.15 °C.

Palabras clave: *cero absoluto, experimentos de nivel escolar, gas ideal.*

INTRODUCTION

One of the important challenges for a college physics teacher, when teaching an introduction to the topics of heat and temperature, is to present to the students the idea of an absolute minimum temperature. This is the so-called *absolute zero*, which corresponds to the temperature of -273.15°*C* (0 *K*). Indeed, given that the experiments used to determine the absolute zero temperature are usually performed in advanced thermodynamics courses, the usual procedure in introductory levels consists of passing on the notion based on the authority of a textbook. Unlike other laboratory experiments about heat and temperature, the empirical estimation of the absolute zero typically requires expensive equipment and/or convoluted mathematical calculations. This difficulty is evident when reviewing the available experiments for teaching on this topic (Strange & Lang, 1989; Kim, et al., 2001; Amrani, 2007; Bogacz & Pedziwiatr, 2013).

The aim of this article is to present an original experiment that allows introducing the notion of absolute zero via three different albeit complementary procedures. The first procedure is a simple graphical estimation, which can be performed by both undergraduate and secondary school students. The other two procedures are slightly more complex compared with the first but are still relatively simple, and are designed for undergraduate students of science and engineering. The values we found using the three procedures are: -292.2°*C*, -275.90 ± 15°*C* and -275.74 ± 5°*C*, in excellent agreement with the actual value of -273.15°*C*. The experimental protocol is simple, and it only requires low-cost materials and equipment.

The article is organized as follows. First, we derive an equation that relates pressure with temperature, using the equation of state of ideal gases. Next, we describe the experimental setup, detailing the instruments and materials needed. We then present the results obtained and our estimation of the absolute zero through the procedures mentioned earlier. Finally, we discuss these results, comparing them with other experiments and highlighting key issues to address in a discussion with the students.

THEORETICAL FRAMEWORK: THE RELATION BETWEEN PRESSURE AND TEMPERATURE OF AN IDEAL GAS

According to the equation of state of ideal gases, if we have n moles of gas in a container of constant volume V, the absolute pressure P and the absolute temperature T_K (in Kelvin) of the gas are related by the following equation (Petrucci, et al., 2011; Serway & Jewett, 2008):

$$P = \frac{nR}{V} T_K \tag{1}$$

where $R = 62.32\ mm\ Hg{\bullet}L{\bullet}mole^{-1}{\bullet}K^{-1}$ is the universal gas constant. We know that T_K is related to the temperature in Celsius degrees T through the following relation:

$$T_K = T + T_{\min} \tag{2}$$

In this equation, Tmin is the minimum theoretical temperature that can be reached, which has been estimated to be Tmin= -273.15°C (Petrucci, et al., 2011). Replacing equation (2) on equation (1) we have:

$$P_K = sT + sT_{\min} \tag{3}$$

where $s = nR/V$. This equation represents a line with slope s and intercept on the abscissa equal to $T_{\min}$, as shown in figure 1. It is easy to note that decreasing P implies decreasing T. However, given that P can only take positive values (it is an absolute pressure, not a difference in pressure), there is a point below which T cannot decrease further (i.e., the temperature T corresponding to a pressure $P = 0$). This point corresponds to the minimum possible temperature, or absolute zero.

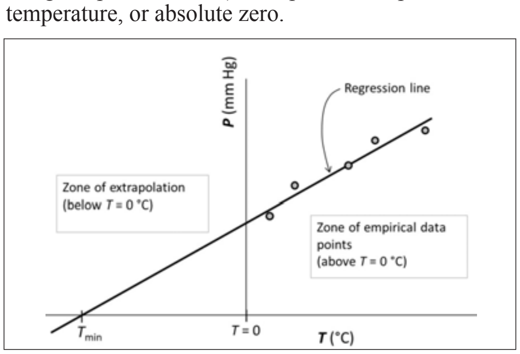

Figure 1. A plot illustrating the theoretically-guided procedure to estimate the absolute zero. If we empirically obtain P, T data points in the range of temperature above 0°C, we can calculate a linear regression on these points. For an ideal gas, we expect a linear relationship between P and T. We then use the regression line to extrapolate values below 0°C, which makes it possible to obtain the intercept of the line on the abscissa (where the pressure of the gas is expected to become zero).

Let us assume we have n moles of air at a temperature $T = 0$°C and we measure its absolute pressure P. Then we raise the temperature to a new known value and measure P again. By repeating this procedure, we obtain a set of (P, T) value pairs that can be plotted. Let us also assume we perform only measurements above 0°C, to avoid experimental complications. If we assume that air is an ideal gas, then within experimental error the measured values should lie on a straight line as the one depicted in figure 1. Such a line can be estimated by simple linear regression, and then compared with the theoretical line given by equation (3). If $T_{\min}$ is an unknown value to estimate, then by extrapolating (P, T) to values below 0°C (see figure 1), it is possible to estimate $T_{\min}$ by comparing the expected intercept $sT_{\min}$ with the empirical intercept given by the regression equation. This is the basic idea underlying the experiment that we describe in the following section.

INSTRUMENTS AND MATERIALS

In this section, we describe the instruments and materials used in our experiment. Note that there are alternative materials that could perform the same functions, and, therefore, we are only suggesting what we used. Instruments:

- An arterial pressure manometer
- A thermometer to measure liquid water temperature.

Materials:

- A small, heat-resistant glass flask (approximate volume 50 cm^3).
- A short piece of flexible plastic tubing (to connect the flask and the manometer)
- A few containers with water (to serve as water baths)
- A kitchen-type water boiler (to raise water temperature)

Figure 2 shows a diagram of the experimental setup. The manometer is tightly connected to the flask through the piece of tubing. The manometer allows measuring the air pressure inside the flask, which is placed in the water bath. After a few minutes, the air inside the flask will attain thermal equilibrium with the surrounding water. The thermometer is used to measure the water temperature, providing an indirect measure of the air temperature. Figure 3 show different views of the experimental setup.

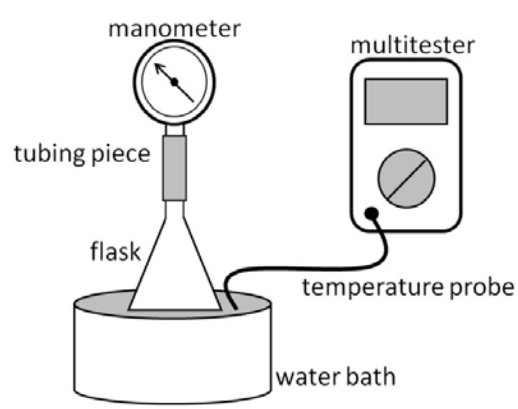

Figure 2. Diagram of the experimental setup.

Figure 3. The left image shows the arterial pressure manometer connected to the flask via a piece of flexible tubing. The middle image shows the flask is partially submerged in the water. Pressure is measured with the manometer, and water temperature with a multi-tester. The right image shows the five containers with water at different temperature used in the experiment. Water is heated using the boiler shown at the right side.

A manometer is connected through plastic tubing to a glass flask containing air. The flask is introduced in the water, whose temperature is measured with a probe connected to a multi-tester. This temperature is the indicator of the air temperature inside the glass.

PROCEDURE AND RESULTS

To perform the measurements we start by submerging the glass container in the water bath containing a mixture of water and ice, to obtain a temperature close to 0°C. Once the flask is in thermal equilibrium with the bath, we connect the flask to the manometer using the piece of tubing. For the equilibrium temperature we calibrate the manometer at 0°C. We know that the pressure at the manometer P_m and the atmospheric pressure P_{atm} are related to the absolute pressure according to:

$$P = P_m + P_{at} \tag{4}$$

Let us assume that atmospheric pressure corresponds to standard conditions (P_{atm} = 760 *mm Hg*). Since the resolution of our manometer was 1 *mm Hg* and we observed values close to zero for the first measurement, we approximated the value of *P* for the first measurement to 760 *mm Hg*. Once we have the first pair of *P*, *T* values, we place the flask (the manometer must remain attached) successively to rest of the water baths, each with an approximate temperature of 10°*C* higher than the preceding one. On each case, we wait 1-2 minutes for the establishment of thermal equilibrium between the air and the water bath, and we measure again *T* and P_m. Then we calculate *P* using equation (4).

Table 1. Results of one experiment

T (°C)	Pm (mmHg)	P (mmHg)
2.2	0	760
15.9	40	800
45.3	112	872
69.3	178	938
95.5	244	1004
100.2	254	1014

Table 1 shows the experimental values we found for *P* and *T*. The first column contains the water bath temperature *T*(°*C*). The second column contains the manometer pressure P_m (*mm Hg*) and the third column contains the absolute pressure $P = P_m + 760$.

The first estimation of the absolute zero, which we will designate as T_{min1}, it is based on a simple graphical procedure illustrated in figure 4. This is a straightforward procedure that does not aim to be accurate, but only to provide a first approximation to the minimum temperature, without requiring statistics or algebra.

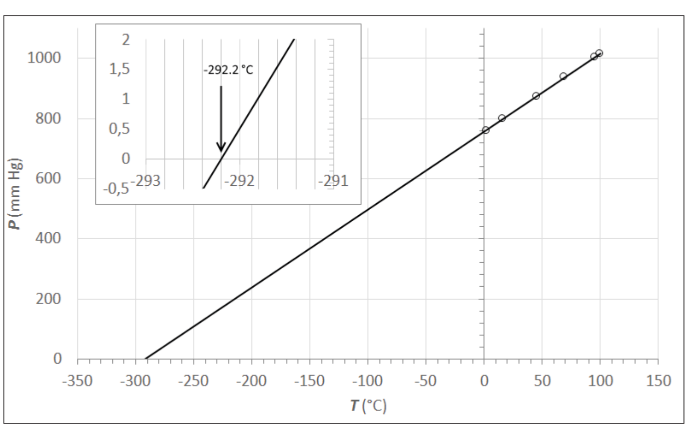

Figure 4. Scatter plot of values from Figure 4 (data in table 1), including an extrapolation of the best-fit line to graphically determine the value of the minimum temperature. The inset shows enlarged the area where the graphical estimation was performed.

The students can accomplish this procedure using graph paper and a rule to trace an eye-estimated line of best fit to the experimental points. The line should extend (extrapolate) until it intersects the abscissa axis (i.e., the temperature axis). The temperature value at the point of intersection between the best-fit line and the temperature axis, corresponds to the absolute zero temperature, in Celsius degrees (see Figure 4). In this example, the value obtained in the estimation was T_{min1} = -292.2 °C.

The other two procedures we present to estimate T_{min} are slightly more elaborated and complex and are based on simple linear regression. Indeed, Figure 5 shows a scatter plot of the *T* and *P* values of table 1, alongside the linear regression line. In the figure, the coefficient of determination R^2 is also shown, which in this case it corresponds to an almost perfect linear fit $R^2 = 0.9996$.

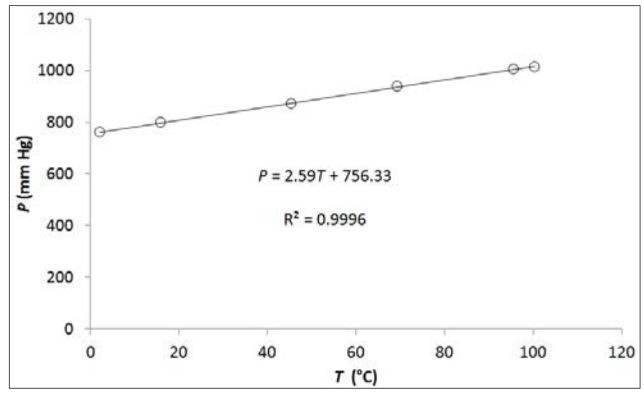

Figure 5. Scatter plot of T vs P values, obtained for one experiment (data in table 1). Regression line, equation and R2 value are also shown.

Therefore, within experimental error, the scatter plot corresponds to a line, in good agreement with the theoretical model introduced in section 2 (see and figure 2).

The second estimation of the absolute zero, which we will designate as T_{min2}, it is obtained directly from the regression line, taking *P* = 0 and solving for *T*:

$$T_{min\,2} = -\frac{756.33\ mmHg}{2.59\ mmHg \cdot °C^{-1}} = -292{,}02\ °C \tag{5}$$

This value only differs by 6.9% from the accepted value of -273.15°*C*, which constitutes an excellent estimation. The third estimation, which we will design as T_{min3}, leads to a much more accurate value, and results from a comparison among the regression line intercept on the abscissa with the theoretical intercept T_{min}, given by equation (3). To do this, we need to determine the value of *s*. As we saw in the previous section, it is given by:

$$S = \frac{nR}{V} \tag{6}$$

It has been shown empirically that the volume occupied by 1 mole of an ideal gas at standard conditions of pressure and temperature (760 *mm Hg* and 0°*C*) is 22.4 *L* (Petrucci, et al., 2011). This value is known as the *molar volume*. If we assume that the air behaves as an ideal gas, and since we know the flask volume 50 $cm^3 = 50\times10^{-3}$ *L*, then the flask contains approximately 2.23×10^{-3} *moles*. Using these values for *n* and *V*, and considering $R = 62.32\ mm\ Hg \cdot L \cdot mole^{-1} \cdot K^{-1}$, we obtain:

$$s = 2.78\ mmHg \cdot °C^{-1} \tag{7}$$

By comparing equation with the regression equation (see Figure 6), it is easy to see that the intercept of the regression line must be equal to sT_{min3}, that is:

$$sT_{min\,3} = 756.33\ mmHg \tag{8}$$

from which we solve for T_{min3} to obtain:

$$T_{min\,3} = \frac{756.33\ mmHg}{2.78\ mmHg \cdot °C^{-1}} = 272{,}06\ °C \tag{9}$$

In contrast with the second procedure, which produced a negative value, in this case we obtain an absolute (positive) value for the minimum temperature. This value differs in 20.09°*C* from T_{min2} but is much closer to the accepted value of -273.15°*C*. Therefore, within experimental error, we obtained a remarkable estimation, considering the experiment's simplicity.

Once we complete all the measurements, we suggest placing the flask again in a water bath with ice at a temperature close to 0°*C*. We should obtain a measurement of P_m close to zero. If we verify this, we have evidence to assume that the number of moles of air within the flask has remained constant, which is an essential requisite for a correct interpretation of the results.

By repeating the procedures 2 and 3 several times we can elaborate further and treat the obtained values statistically, obtaining means and standard deviations. We can interpret the latter as a measure of both variability and experimental error.

Table 2: Estimations of Tmin2 and Tmin3 values from four separate experiments

Experiment	Tmin2 (°C)	Tmin3 (°C)
1	-292.92	-272.06
2	-272,96	-270.99
3	-257.67	-279.91
4	-280.06	-279.99
Mean (± SD)	-275.90 (± 15)	-275.74 (± 5)

Table 2 summarizes the results we obtained in 4 repetitions of the experiment. The values of 'Experiment 1' correspond to the values presented previously for the procedures 2 and 3. The data in the table show that the mean value for T_{min3} is a bit more accurate than the mean value for T_{min2}. In addition, the variability (measured by the SD) of T_{min3} estimations is much smaller than that of T_{min2}. In the next section we refer to these discrepancies.

DISCUSSION AND CONCLUSIONS

The discussion that follows contains several ideas that can be used by teachers with the students in their analysis of results of the procedures 2 and 3.

A first issue is related to the difference in the mean values for T_{min2} and T_{min3} (see Table 2). As we have seen, these two values have a reasonable accuracy (they both differ by a couple of degrees from the actual value). Nevertheless, their precision (the variability in the data) is very different. To interpret this difference we must analyze the different procedures which led us to T_{min2} and T_{min3}. In the second procedure, we obtained T_{min2} directly from the regression line, which in turn had been obtained from empirical data. In contrast, to calculate T_{min3} we carried out a comparison among the theoretical and the regression lines. For this comparison, we estimated the value for the intercept on the abscissa using numbers from chemistry and physics textbooks. That is to say, unlike the case of T_{min2}, we used numbers with a large precision. This allows explaining the differences in precision between both estimations.

A second issue about the experiment that is worth examining refers to the assumption of an ideal gas. By comparing the regression and theoretical lines, we see an excellent agreement between them. If we compare the regression slope (2.59 mm Hg•°C^{-1}) with the theoretical slope (2.78 mm Hg•°C^{-1}), we see only a 6.8% difference. These results, therefore, allow a simple interpretation: as a first approximation, the air can be modelled as an ideal gas.

Finally, it is interesting to place our results in the context of previously reported experiments aimed at estimate empirically the absolute zero temperature. In the next paragraphs, we analyze some estimations of Tmin found in the literature of science education and we compare them with ours.

Bogacz and Pedziwiatr (2013) report a method in which they measure the pressure inside a glass bulb with air, at different temperatures. They use an electronic pressure sensor connected to a computer. The value they report is -267 ± 15°*C*, a number less accurate and precise than ours. And besides, the requirement of an electronic-computerized system implies a more sophisticated setup.

Kim et al. (2001) determined volumes of air with water vapor at different temperatures, and used these values to estimate the corresponding volumes of dry (pure) air. With these latter values, they build a *V* vs *T* curve that allows them to estimate, also by extrapolation, the absolute zero. The experimental method is fairly simple, although the calculations are more complicated than ours. The reported value by Kim et al. is -276.01 ± 8 °*C*. This number is not as exact as our values, and its precision surpasses that of T_{min2} but not that of T_{min3}.

Strange and Lang (1989) estimated the absolute zero from a *V* vs *T* line using an experimental setup with a flask, a syringe, a water bath, a thermometer and a manostat. The experimental procedure is fairly straightforward, although slightly more complex than ours, and it entails measuring both *V* and *T* for the air enclosed in the syringe. In this case, the obtained value is -276 ± 21 °*C*, which is less accurate and less precise than ours.

Amrani (2007) proposes a method of determination of absolute zero that requires a computer, specific software, an absolute zero apparatus (a hollow copper sphere), an absolute pressure sensor, a thermistor, and a water bath. In this case, several values of *P* and *T* are measured, and the author reports a value of -270 ± 4°*C*, whose accuracy and precision are better than our values. Nevertheless, the experiment requires sophisticated and expensive instruments.

As a general conclusion, we assert that our experiment is comparatively accurate, precise, simple, and cheap. We also proposed two approaches to the estimation of the temperature (T_{min2} and T_{min3}) which can be compared both in a single experiment and in separate repetitions. These procedures involve relatively simple calculations and can provide interesting discussion material for students, which can serve to improve the learning of the physical concepts.

In our experience as physics teachers, the idea of a minimum temperature is relatively difficult to grasp by the students. If we approach the subject on purely theoretical considerations, the concepts are usually harder to learn. We think that an empirical approach such as the one we presented can provide the required material for a more profound and significant understanding.

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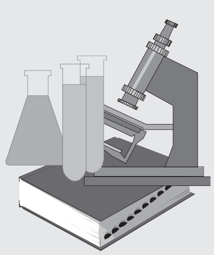
Received 26-05-2016 /Approved 15-05-2017



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Controlling cognitive load of high school student in biology class

Control de la carga cognitiva de estudiantes de bachillerato en la clase de biología

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Abstract

When the capacity of working memory is exceeded it leads to trouble in the cognitive process. The learning process will be more influenced by mental effort than by cognitive processing. In this situation students have a demandon their cognitive system termed cognitive load (CL). This study describes students CL both in a conventional biology class and after the integration of four CL controlling strategies in the conventional teaching strategy. The four CL controlling strategies were the framing technique, the stay and stray strategy, the didactical reduction of teaching material, and the stimulation of prior knowledge by watching videos. The level of cognitive load was described quantitatively based on the result of the statistical analysis of the correlation between the intrinsic cognitive load (ICL), the extraneous cognitive load (ECL), and the germane cognitive load (GCL). Student ICL was discovered by the ability of the student to process information gathered from a complexity worksheet. ECL was shown by the student's mental effort (ME) collected by questionnaire using a subjective rating scale. GCL was revealed through learning achievement (LA) measured by a paper and pencil test. The study was conducted in several high schools in West Java, including a state and private high school (SMA) and an Islamic high school (Madrasah Aliyah). The result demonstrated that during a conventional biology class student CL was at a high level. Integrating four CL controlling strategies into the conventional teaching strategy separately led to different levels of student CL. Three of the four CL controlling strategies, i.e. stimulating prior knowledge by watching video; the framing strategy, and the didactical reduction of teaching content, potentially lowered students' CL. The Integration of stay and stray strategy into a conventional class made no difference to the level of CL compared to that in a conventional class.

Key words: *biology class, cognitive load, framing, stay and stray strategy, didactical reduction, prior knowledge.*

Resumen

La actividad de la memoria de trabajo que excede su propia capacidad provoca contrariedad en el proceso cognitivo y el proceso de aprendizaje será influenciado más por el esfuerzo mental que el procesamiento cognitivo. En esta situación, los estudiantes tienen una carga en su sistema cognitivo denominada carga cognitiva (CC). Este estudio describe la CC de los estudiantes tanto en una clase de biología convencional como después de la integración de cuatro estrategias de manejo de CC en la estrategia de enseñanza convencional. Las cuatro estrategias de control de CC aplicadas fueron la técnica del encuadre, la estrategia de dinámicas de grupo, la reducción didáctica de la materia de enseñanza, y la estimulación de conocimiento previo mediante exposición de videos. El nivel de la carga cognitiva se describió cuantitativamente basado en el resultado del análisis estadístico de la correlación entre la carga cognitiva intrínseca (CCI), la carga cognitiva extrínseca (CCE), y la carga cognitiva relevante (CCR). La CCI del estudiante se descubrió a partir de la capacidad del estudiante de elaborar información adquirida de una hoja de cálculo de complejidad. La CCE se mostró a través del esfuerzo mental (EM) del estudiante recopilado en un sondeo con una escala de calificación subjetiva. La CCR se expuso mediante los logros de aprendizaje (LA) calculado en una prueba de lápiz y papel. El estudio se llevó a cabo en diversas escuelas de educación media en Java Occidental, incluyendo escuelas de educación media (SMA) estatales y privadas así como una escuela de educación media islámica (Madrasah Aliyah). El resultado demostró que en una clase de biología convencional, la CC del estudiante estuvo en un alto nivel. La integración, por separada, de cuatro estrategias de control de CC a la estrategia de enseñanza convencional resultó en diferentes niveles de la CC del estudiante. La integración de la estrategia de dinámicas de grupo a la clase convencional no alteró el nivel de la CC con respecto a la de la clase convencional.

Palabras clave: *clase de biología, carga cognitiva, encuadre, estrategia de dinámicas de grupo, reducción didáctica, conocimiento previo.*

INTRODUCTION

Teaching and learning in a school class is based on the need to develop and to train students' thinking processes. The thinking process relates to the activity of the working memory in which all cognitive processes occur when the student is learning. Working memory has only a limited capacity and can handle a limited number of interactions (Paas *et al*, 2003; Kalyuga, 2011). The capacity of a working memory depends on the student having a level of prior knowledge. If the working memory in a cognitive system has a little trouble the student will have difficulty in learning and the information delivered by the teacher cannot be taken in (Sweller *et al*, 1998; Paas *et al*, 2003). The student will be forced to mentally integrate information, a process that is unrelated to the construction of cognitive schema. In this situation the student has a demand on their cognitive system known as cognitive load.

Cognitive load (CL) consists of three components, intrinsic cognitive load (ICL), extraneous cognitive load (ECL), and germane cognitive load (GCL). ICL relates to the load of information processing received as any learning task is given. ICL has simultaneous interconnections with the working memory. The magnitude of ICL depends on the number of elements that must be simultaneously processed in the working memory and the prior knowledge that has been already absorbed by the learner. The load resulting from the interactivity of the elements varies among and within different subject areas (Moreno & Park, 2010). De Jong (2010) simplifies this by saying that ICL relates more to inherent characteristics of the content of subject matter. ICL cannot be changed by instructional treatments (de Jong, 2010; Moreno & Park, 2010). ECL is the load that student has and it is affected by the instructional system developed by the teacher. ECL is not necessary for learning because it does not directly contribute to learning or to the construction of cognitive schemas (de Jong, 2010). ECL can be eliminated by redesigning the instructional system (Moreno & Park, 2010; de Jong, 2010).Several factors which cause ECL are split attention, the modality principle, and the redundancy principle (Cerpa *et al*. 1996; Sweller *et al*. 1998; Sweller, 2010; de Jong, 2010;). GCL is the result of devoting cognitive resources to schema acquisition and automation rather than to other mental activities. GCL is the cognitive load associated with organizing the learner's knowledge. GCL is caused more by ICL than by ECL (Moreno & Park, 2010). De Jong (2010) stressed that the construction of cognitive schema involves several cognitive processes (e.g. interpreting, exemplifying, classifying, inferring, differentiating, and organizing) which occur when students process information contained within certain tasks of the instructional system. Consequently, instructional designs should stimulate and guide students to engage in schema construction and automation.

CL may be used as an explanation for the effect of the teaching strategy on psychological and behavioral changes which show learning achievement (Moreno & Park, 2010). CL can also be used to explain a level of student difficulty or student inability to construct schema of knowledge. Increased CL can be because of poor instructional design (Sweller *et al* 1998). According to CL theory a reduction of CL is purposed to give more space in the working memory and to give a place for processing new information. The reduction of CL can be done in order to keep mental effort at a minimum during the learning process (Moreno & Park, 2010). Teachers should, in their instructional design, pay attention to keeping a balance between ICL and GCL through altering the factors having an impact on ICL or ECL. De Jong (2010) and Kester *et al* (2010) described the way to reduce ICL and ECL to produce a better way for students to process the content of teaching, such as by activating student prior knowledge, minimizing the number of elements and their interaction, avoiding split attention and reducing redundancy of information, and, finally, enhancing students' learning modality systems. This paper describes the different impacts of the integration of several CL controlling strategies into the conventional biology class of various high schools.

METHODOLOGY

This study was conducted in 12 high schools in Bandung, Sumedang, and Ciamis of West Java Province of Indonesia including state and private high schools (SMA) and Islamic high schools (Madrasah Aliyah; MA). Four strategies to control student CL were integrated into the conventional teaching strategy that was usually used by the teacher, a teaching strategy adapted from the framework for guided inquiry class (Kuhlthau *et al*, 2012). The four CL controlling strategies were 1) the framing technique to avoid students' divided attention and to give a direction to what the students have to learn, 2) the stay and stray strategy to help student by giving peer coaching from outside the group, 3) the didactical reduction (simplification) of teaching material represented by a flow-chart to reduce the number of elements of content, and 4) stimulating prior knowledge by watching videos that shows concepts in a contextual mode and relate to the content that will be learned (see the Appendix for examples of these methods). Several topics of biology which had a different complexity, from very concrete to very abstract content, were chosen as the teaching content. These teaching topics included plant systems and diversity, the coordination system, and the excretory system.

The level of cognitive load was described qualitatively, based on the result of the statistical analysis of correlation among three components of CL. Student ICL was revealed by the student's ability to process information delivered by the teacher or by the tasks of instructional design (IP; information processing). IP was gathered by a complexity worksheet given to the student alongside the teaching process. ECL was shown by the student's mental effort (ME) collected by the questionnaire on a subjective rating scale. GCL was revealed by learning achievement (LA) measured by a paper and pencil test conducted at the end of the teaching. All instruments used to measure student CL were developed as described by Brünken *et al* (2010). The relations among three components of cognitive load are asymmetric (Moreno & Park, 2010), levels of ICL or GCL are shown in another way, through the score of the student's IP or LA whereas the level of ECL is equal to the score of ME. CL was assumed to be at a lower level when IP-LA has a significant positive correlation whereas both IP-ME and ME-LA have a significant negative correlation.

RESULTS AND DISCUSSION

The biology classes of high schools in some districts of West Java are conventionally conducted by the teacher using a teaching strategy adapted from the framework for guided inquiry class (Kuhlthau *et al*, 2012) with common teaching methods such as teacher presentation complemented by a slide power point, questioning, discussion, practical activities, and student presentations. To enhance student motivation and stimulate a student's prior knowledge apperception was commonly stimulated by questioning, asking about the content delivered in previous lesson. Interpretation of statistical correlation on student CL components revealed that the CL of the students commonly stayed at a high level (Table 1). Teaching strategies in a conventional biology class could not yet yield a level of ICL that could reduce the level of ECL because the negative correlation of IP-ME was not significant (Table 1). In some cases, such as in SMA Ciamis, correlation of IP-ME showed a positive value of coefficient correlation indicating that some students used their ME to develop final cognitive schemas. All these teaching strategies when employed in a conventional biology class in all schools showed a positive impact on decreasing ICL and had a positive effect on GCL as indicated by a significant positive correlation of IP-LA (Table 1). However, the GCL was also imposed by ECL because the negative correlations of ME-LA were not significant. The result means the students have difficulty in constructing a schema using their cognitive system. They used much mental effort to gather the concepts or information delivered by the teacher while the teaching process was going on. It was shown by the explanation of de Jong (2010) that if the load is imposed by mental activities that interfere with the schemas' construction or automation it will have negative effects on learning. Moreno & Park (2010) stressed that the purpose of instruction is to keep mental effort at a minimum during the learning process.

Table 1. Correlation among CL components showing a level of student CL in biology classes of high school without integration of CL controlling strategy. Cells with gray shading indicate a significant correlation (p<0,05).

CL Components	SMA Bandung	SMA Sumedang	SMA Ciamis	MA Bandung
IP – LA	0,664; p=0,000	0,512; p=0,001	0,171; p=0,334	0,485; p=0,007
IP – ME	-0,208; p=0,237	-0,221; p=0,183	0,010; =0,956	-0,094; p=0,620
ME – LA	-0,295; p=0,090	-0,047; p=0,786	-0,023; p=0,897	-0,290; p=0,120

The integration of CL controlling strategies into conventional biology classes of high schools brought a better student CL level compared to the conventional teaching strategy alone (Table 2). The use of video in the apperception phase to stimulate student prior knowledge and the use of framing during the teaching process separately gave a significant negative correlation of IP-ME and a significant positive correlation of IP-LA (Table 2). These results show that CL controlling strategies integrated into the conventional strategy could reduce student ICL and positively contribute to decreasing student ECL. These show that two strategies have a potential effect on reducing the level of student CL. We predict that the use of tables and dichotomous diagrams containing keywords or clues act as a kind of framing, directing students to what they should do while they are doing the instructional task. Keywords or clues mean it is easier for the student to construct schema, thus they can finish the task better. A dichotomous diagram with keywords or clues gives a basic schema in a concrete manner. Gibney & Lengel (1968) explained that the need of concrete learning experiences is inversely proportional to intellectual capability. A student with less intellectual capability needs more concrete examples. On the other hand, stimulation of student prior knowledge using video has the advantage of reducing student CL because the information conveyed in a video is un-fragmented and enclosed in an audio-visual organization. The un-fragmented information means that elements of information are delivered in an interconnected way, a method that means it is easier for students to recall the knowledge they already have. In this situation working memory will have more space for information processing and assimilation will proceed more efficiently.

Table 2. Correlation of CL components showing a level of student CL in biology classes of high school with integration of CL controlling strategies. Cells with gray shading indicate a significant correlation (p<0,05)

CL Components	Stay & Stray	Framing	Didactical reduction	Stimulating Prior Knowledge by Video
IP – LA	0,632; p=0,000	0,475; p=0,003	0,635; p=0,000	0,420; p=0,021
IP – ME	0,106; p=0,558	-0,338; p=0,023	0,003; p=0,985	-0,574; p=0,0009
ME – LA	0,133; p=0,462	-0,078; p=0,652	-0,465; =0,004	-0,348; p=0,0598

In other situations, the use of didactical reduction of teaching material gave a different result compared to the two strategies mentioned above. Didactical reduction represented by a flowchart gave an insignificant correlation of IP-ME (Table 2) meaning there is no clear connection between IP and ME. This statistical correlation indicated that during the teaching process there was no necessary relationship between ICL and ECL. When student's ICL is lower, ECL can stay either at a lower or higher level. In this situation, however, the decreasing ECL level affected the level of GCL as shown by a significant negative correlation of ME-LA. Student GCL was more affected by ICL because the correlation of IP-LA leads to a significant positive correlation. These results revealed that didactical reduction had a potential effect for reducing student CL, even though the cognitive processing during the teaching process was quite disturbed by ECL. This potential effect of didactical reduction on reducing student CL probably come from the depiction effect of teaching content delivery using a flow-chart. A flow-chart is a kind of visualization of teaching material changing the text into a visual format. A flow-chart contains a reduced number of information elements and shows how those elements interact with each other giving a mode in which the student will acquire the content easier than a text. Haslam &Hamilton (2010) found that visualization facilitated the student to develop a mental representation of the concept. Additionally, Sweller (2005) specified that visualization or a picture as a kind of representation helps the student to understand the content more easily. Mayer& Moreno (2003) noticed that visualization of a concept has an advantage for the student with poor prior knowledge.

The use of the stay and stray strategy gives students more opportunities to help each other during the teaching process, especially when students acquire new information. In the stay and stray strategy students of one group can go to another group to ask for information and an explanation of that information. Unfortunately, the integration of the stay and stray strategy in the teaching process had less potential to reduce student CL because only IP-LA correlation yielded a positive value of coefficient correlation and occurred significantly. The IP-ME and ME-LA correlation led to an unexpected relationship (Table 2). Both IP-ME and ME-LA correlations were positive and insignificant; this condition shows that the stay and stray strategy could not expressively reduce student ECL. It means that to come to a high level of LA student needs more ME rather than LA. Stay and stray strategy cannot manage student ECL as yet. It may come from the impact of the student visitation step, in which students could visit another group to complete their observation but the visited group was not ready to give explanations to the visiting group. We found that the visited group could not give an accurate explanation to the guest group because students in the visited group had difficulty processing the information delivered by instructional tasks, such as from their observation. We guessed two possible explanations for this situation: *first*, students had no sufficient prior knowledge to assimilate new knowledge (Mayer & Moreno, 2010), and *second*, the information that students collected from their observations was too complex; having a large number of interacting elements that students needed to process in their working memory. A high interactivity content by its nature consumes more of the available cognitive resources (de Jong, 2010).

CONCLUSIONS

Student CL during the teaching process in high schools' conventional biology classes was considered to stay at a high level. Integrating four CL controlling strategies into the conventional teaching strategy separately lead to different levels of CL. The use of video to stimulate student prior knowledge, framing, and didactical reduction of teaching content took the teaching process into a lower level of student CL. Integrating stay and stray strategy into the conventional class gave no better student CL level, in other words, the students still had difficulty processing the information meaningfully. We suggest that to control student CL in biology class teachers should pay attention to several factors affecting students' CL rather than only one factor. Teachers may use a minimum of two or more CL controlling strategies simultaneously integrated into their instructional design.

ACKNOWLEDGEMENTS

This project was supported by a research grant 2015 of Universitas Pendidikan Indonesia (UPI). We express our deep appreciation to school principals and biology teachers of all senior high school (SMA/MA) who participated in this research and who provided the appropriate biology class. Thank you to the following students, who worked hard to collect the complete data: Hana Azalia (S1), Rahadian Raksabrata (S1), Kiki Santriana (S1), Rifki Risma Munandar (S2), Santi Sri Rahayu (S2), Rosinta Septiana (S2), Tuti Garnasih (S2), Novi Indria Suryani (S2), and Mira Andriani (S2).

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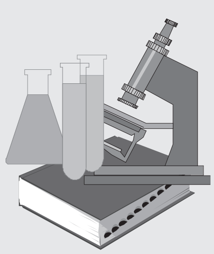
APPENDIX

Teaching steps of conventional teaching strategy and integrating controlling cognitive load strategies in conventional teaching of Biology Class of Senior High School

Stage	Conventional Strategy*	Controlling Cognitive Load Strategies			
		Stay & Stray	**Framing**	**Didactical Reduction**	**Stimulating Prior Knowledge by Video**
Apperception (Open & Immerse)	Asking student'sexperiences relating to teaching contents and to the current problem, to open student's mind.	Asking student'sexperiences relating to teaching contents and to the current problem, to open student's mind.	Asking student'sexperiences relating to teaching contents and to the current problem, to open student's mind.	Asking student'sexperiences relating to teaching contents and to the current problem, to open student's mind.	Asking student'sexperiences relating to teaching contents and to the current problem, to open student's mind. Watching videos relating to teaching content, such as how the kidney works, the influence of hormones on other coordination organs, and plant biodiversity, to stimulate or elicit prior knowledge
Explore	Teacher presents teaching content using a slide power-point. Student works in a group to search out all information relating to teaching content, from text books or internet.	Teacher presents teaching content using a slide power-point. Student works in a group to search out all information relating to teaching content, from text books or internet.	Student works in a group to search out all information relating to teaching content, from text books or internet, using table and dichotomous diagrams containing keywords or clues (as a framing from the teacher)	Teacher presents teaching content using a flow-chart (a didactical reduction of teaching content from text book to flow-chart)	Teacher presents teaching content using a slide power-point. Student works in a group to search out all information relating to teaching content, from text books or internet.
Identify	Student works in a group to identify the important information and formulates questions	Student works in a group to identify the important information and formulates questions	Student works in a group to identify the important information through answering several questions already written in the worksheet.	Student works in a group to identify the important information and its relationships from the flow-chart. Student formulates questions	Student works in a group to identify the important information and formulates questions
Gather	Student works in a group to collect the data through observation. Data should be used to answer the question.	In one group: One or two students visit another group to ask for the important data relating to their question (stray). Others members stay in the group to receive visitors from another group and answer the questions from the visitors (stay).	Student works in a group to collect the data through observation, however she/he should pay attention to the table, dichotomous diagram, or questions prepared by the teacher in the worksheet	Student works in a group to collect the data through observation. Data should be used to answer the question.	Student works in a group to collect the data through observation. Data should be used to answer the question.
Create & Share	Student discusses in a group the answer to the question, using data and presents (shares) the results in the class. Student concludes whether the question is answered or not.	Student discusses in a group the answer to the question, using the data that they collected in the group and that they obtained from other groups. Student presents the data and shares the results in class. Student concludes whether the question is answered or not	Student discusses in a group the answer to the question, using data and presents (shares) the results in the class. Student concludes whether the question is answered or not.	Student discusses in a group the answer to the question, using data and presents (shares) the results in the class. Student concludes whether the question is answered or not.	Student discusses in a group the answer to the question, using data and presents (shares) the results in the class. Student concludes whether the question is answered or not.
Evaluation	Student answers the teacher's question about teaching content and process.	Student answers the teacher's question about teaching content and process.	Student answers the teacher's question about teaching content and process.	Student answers the teacher's question about teaching content and process.	Student answers the teacher's question about teaching content and process.

*Note: the framework of conventional teaching strategy was adapted from the framework of guided inquiry class (Kuhlthau et al, 2012)

Received 2-06-2016 /Approved 15-05-2017



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Using a word association method to assess knowledge structure of renewable energy sources at primary level

Utilización de un método de asociación de palabras para evaluar la estructura del conocimiento de las fuentes de energía renovables

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Abstract

The word association test is a tool suitable for analysing students' knowledge structure. Using association maps, it can describe the quantitative and qualitative features of the stimulus words and associations as well as their interconnectedness. Our study demonstrates application of the method through the analysis of 4th and 7th graders' conceptual structures related to renewable energy sources. The results showed a more complex conceptual structure resulting from the 7th graders' age, a more complex conceptual system in city learners and a more coherent knowledge in boys. Due to its expressive and informative nature, the word association test is an ancillary evaluation method recommended to teachers as well, with the simplification that in their case it would be sufficient to analyse the quantity and quality of the associations and, based on these, create an association map given the fact that the latter simultaneously shows the nature of the relationships between the stimulus words, too.

Key words: *word association test, advantages, disadvantages, renewable energy, knowledge structure*

Resumen

El test de asociación de palabras es adecuado para analizar la estructura de conocimiento de los alumnos. Con la ayuda de los mapas de asociaciones, se consigue ilustrar gráficamente las características cuantitativas y cualitativas de sus asociaciones y sus palabras destacadas, además de la correlación entre ellas. En nuestro estudio sobre el uso del método, presentamos el análisis de la estructura conceptual de las energías renovables de alumnos de cuarto y séptimo curso. Los resultados demostraron una estructura conceptual más compleja en los cursos con alumnos de edad más avanzada, un sistema conceptual más exhaustivo en el caso de los estudiantes de ciudad, y conocimientos más profundos en el caso del género masculino. El método de asociación de palabras es un método de evaluación complementario recomendado también para los pedagogos, por su expresividad y su carácter informativo, con la simplificación que puede ser suficiente mediante un análisis cuantitativo y cualitativo de dichas asociaciones. Según esos datos se puede preparar un mapa de asociaciones, ya que al mismo tiempo se presenta el carácter de las relaciones entre las palabras destacadas.

Palabras clave: *test de asociación, ventajas, desventajas, energía renovable, estructura conceptual*

INTRODUCTION

The word association method has so far been applied at different levels of science education. Within the evaluations made with word association tests the smallest number of studies can be found in the field of analyses of primary school students'knowledge structure. Ercan, Tasdere and Ercan (2010) used this method to study 7th graders' conceptual shift in the field of astronomy. In his research Armagan (2015) found how 6th and 7th graders' metacognitive conceptual system of science research changed after a 5 days' project on research methodology. He thinks that from a data processing point of view, the word association method is time-intensive; however, through conceptual maps, it allows a more transparent and informative evaluation than traditional descriptive statistical procedures in regard to changes in students' conceptual structures. It was primarily the structure of chemistry and biology concepts and its changes that researchers analysed in secondary school students using this test. In their research carried out on 8th and 12th graders Kostova and Radoynovska (2010) reported how they had motivated their students in the course of a special, 12-month-long biology learning period using conceptual maps and the word associatiom method. Kluknavszky and Toth (2009) used this method to study the concepts of groups of 7th through 10th graders related to air pollution. In their study they concluded that the word association method is suitable for mapping students' knowledge structure, monitoring the development of the groups of students' thinking, comparing the various groups and for exploring misconceptions. In a targeted teaching period Nakiboglu (2008) studied how students' conceptual knowledge of atomic structure changed. He concluded that the word association test is suitable for revealing changes that occurred during teaching.

The highest number of examples of the application of the word association method in evaluation can be found in higher education. Cardellini (2000) studied the knowledge level of first–year students of engineering in the field of general chemistry (pH, mole, binding, state of matter, solution, reaction) before and after a special development training. He thinks that this method helps to map deficiencies and misconceptions among basic concepts. Raviolo, Martine and Aznar (2010) analysed the conceptual shift for chemical equilibrium using word association following a course that applied graphs and a consistent representation of chemical particles. The evaluation confirmed the efficiency of the course, namely that the students' understanding of chemical equilibrium had become far deeper, a fact that could be deduced from the number and nature of correlations in the association maps. In their study of biology teacher trainees Dikmenli, Cardak and Kiray (2011) studied students' alternative knowledge of genes, Kurt and Ekici (2013) that of viruses, whereas Hastürk and Dogan (2016) investigated basic concepts of environmental protection, categorised students into groups based on their alternative knowledge and then drew conclusions pertaining to the application of methods that promote learning.

The above methods confirm the multiple advantages of the word association method in the analysis of students' scientific knowledge. However, they do not describe how it can be used in practice by a school teacher or what its advantage is over evaluation of students' knowledge based on traditional performance assessment tasks. In this study it was our aim to shed light, through an evaluation of the conceptual structure of renewable energy using the word association test, on how this method can be simplified for use by school teachers.

METHODOLOGY

The main objective of our study was to map students' conceptual system and its structure related to the topic of renewable energy. This research is also a precursor to a study of attitudes towards renewable energy, which will allow us to assess primary school students' knowledge, emotions, and attitude related to renewable energy. The study described here helps identify students' knowledge related to renewable energy that represents one part of their permanent knowledge to later serve as a basis for the attitude questionnaire. The method used in this study was the free word association test. During the study we were also actively looking for ways through which a simplified form of the method could be made available to school teachers as well.

In this study we were looking for answers to the following questions: 1) What is the nature of the studied students' concept map of renewable energy and related knowledge in 4th and 7th grades? 2) What correlations can be observed between the various stimulus words? 3) What is the number of the associations given for the stimulus words and how strong is their connection to the stimulus words? 4) What are the most frequent associations and correlations that could function as a basis for the attitude questionnaire? 5) What effect do influencing factors (gender, village, and city) have on the strength, number and quality of the stimulus words and the associated concepts in 4th and 7th grades?

Sample and method

The survey, involving a total of 174 Hungarian students in their 4th and 7th years, was carried out in February and March 2016. The students' levels of cognitive development and curriculum-dependent prior knowledge of renewable energy are different in the two years, a fact that we presume should be markedly represented in our study, too. As regards the settlement distribution of the study sample, the students came from schools in two cities and two villages not or only slightly larger than 5000 inhabitants each (Table 1).

Table 1. Distribution of the study sample

	village	city	grade 4	grade 7
boys	38	41	46	33
girls	53	42	44	51
total	91	83	90	84

The method applied in the study was the free *word association test*. The teachers were informed of the purpose of the association test, as well as the mode and time of the survey, before the assessment. They introduced the tests in the 4th and 7th grades that they were teaching and forwarded them to the teachers who later evaluated them. In the word association test learners had to attach associations to various stimulus words. In our study the learners had 2 minutes at their disposal for each stimulus word to describe the assocations related to the given stimulus, which they had to list under one single column. An important factor in choosing the stimulus words was that each of them should be covered in the curriculum.

The stimulus words we studied were the following: *renewable energy, energy saving, power station, and heating.* During evaluation of the word association tests both the associations attached to the various stimulus words and the strength of the relationship between the stimulus words can be studied. The strength of the relationship between the stimulus words can be expressed with the relatedness coefficient (RC) suggested by Garskof and Houston.

Calculation of the Garskof-Houston relatedness coefficient is represented through an example taken from our study (Garskof & Houston, 1963). As mentioned before, the four stimulus words used in the survey were *renewable energy, energy saving, power station, and heating*. All learners wrote a related list of associates for each stimulus word. The following is an example written by a 7th-grader:

> *"Renewable energy: power, wind turbine, water, sun, solar cell. sea, hydroenergy, nuclear energy.*
>
> *Energy saving: saving money, turn off the power, solar cell, reasonableness, power station, wind turbine*
>
> *Power station: water, wind, sun, coal, heating, electricity,*
>
> *Heating: furnace, stove, warm, coal, wood, gad, convector, winter, cold, underfloor heating."*

The value of RC needs to be calculated for every pair of stimulus words (renewable energy – energy saving, renewable energy – power station, renewable energy – heating, energy- saving – power station, energy saving - heating, and power station – heating).

Let's take the example of the calculation of the RC value for the above learner's pair of stimulus words: renewable energy - energy saving. First we examine to which stimulus word the learner provided the most associates. In this case this is the list regarding renewable energy, which contains 9 elements including the stimulus word itself while the list regarding energy saving only has 7 elements. Following Garskof and Houston (1963), we progress toward the stimulus word starting the ranking of the associates at the end of the list that has more elements (in our example this is nuclear energy, given the rank number 1) and the stimulus word itself is also assigned a ranking (in our case this number is 9). Then the elements of the list made up of the second member of the pair of stimuli are also ranked. The stimulus word (energy saving) here is given the ranking of the previous stimulus word (9), and then we rank the associates in the list in descending order (wind turbine is given the ranking 3). As the second list contains fewer elements (7, including the stimulus word), there will be no associations with the rankings 1 and 2. Having ranked all the elements, we examine whether there are identical associates (in our example, wind turbine and solar cell are associates for both stimulus words) in the lists for the two stimulus words and substitue their values in Garskof and Houston's (1963) RC formula (Table 2). In the numerator of the formula we have the sum of the products of the ranks of the identical associates of the examined stimulus words (in our example, for wind turbines it is 7x3, plus 4x6 for solar cell = 45). In the denominator of the formula we have the sum of squares of the elements of the longer list minus one (in our case, the sum of squares of the 9 elements for renewable energy is 295, minus 1= 294). This means that for the pair of stimulus words the value of RC, which expresses the strength of the interrelatedness of the two stimulus words, is 0,15 (Table 2). We calculate the RC value for each pair of stimulus words for every child and obtain the mean RC values for the examined pairs of stimulus words for the given group of learners. We use these values to construct the map of correlations for the given stimulus words for the particular group of learners according to data on the strength of relatedness defined by Cardellini and Nakiboglu (2008) (Table 3)

Table 2. Calculating relatedness coefficients (RC) in cases of different numbers of associations

Associations with stimulus word A	Rank	Associations with stimulus word B	Rank	Garskof–Houston-relatedness coefficient
Stimulus word (A) RENEWABLE ENERGY	9	Stimulus word (B) ENERGY-SAVING	9	$\mathrm{RC} = \dfrac{\overline{A}\cdot\overline{B}}{\sum n^2 - 1}$
power,	8	saving money,	8	
wind turbine,	7	turn off the power	7	**RC = 7x3 (wind turbine)+ 4x6(solar cell) =0,15**
water,	6	solar cell,	6	
sun,	5	reasonableness,	5	**92+82…..+ 22**
solar cell	4	power station,	4	
sea	3	wind turbine	3	
hydroenergy	2			
nuclear energy	1			

RESULTS AND DISCUSSION

Relationship between stimulus words

Our first step was to construct concept maps for stimulus words based on the learners' responses. Before this step, we first determined the strength of Garskof–Houston's relatedness coefficient between the stimulus words for every learner and then calculated averages for the obtained results.

We took the relatedness coefficients determined by Cardellini and Nakiboglu (2008) as a starting point for making conceptual networks (Table 3.)

Table 3. Strength and mode of notation of the relatedness coefficients in the concept network

Value of relatedness coefficient	Strength of relatedness	Notation
0,03 – 0,06	weak	
0,07 – 0,10	medium	
0,11 –	strong	

In our study we first looked for answers to the questions about the nature of *the concept network of 4th and 7th graders involved in the study related to renewable energy and related knowledge on the one hand,* and the *kind of relationships that could be observed between the stimulus words, on the other.* To answer these questions, we constructed the concept map of the stimulus words based on Garskof–Houston's relatedness coefficients. (Table 4, Figures 1 and 2).

Table 4. Relatedness coefficient values of stimulus words in 4th and 7th grades

	renewable energy		energy saving		power station		heating	
	Grade 4	Grade 7	Grade 4	Grade 7	Grade 4	Grade 7	Grade 4	Grade 7
renewable energy	-	-	0,06	0,08	0,05	0,11	0,03	0,01
energy saving			-	-	0,02	0,04	0,03	0,01
power station					-	-	0,03	0,02
heating							-	-

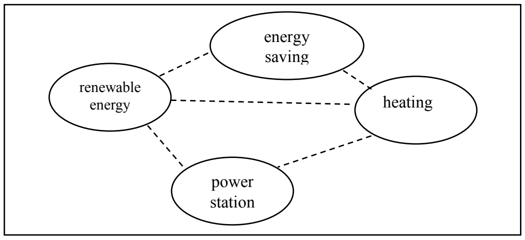

Figure 1. 4th graders' conceptual network of stimulus words

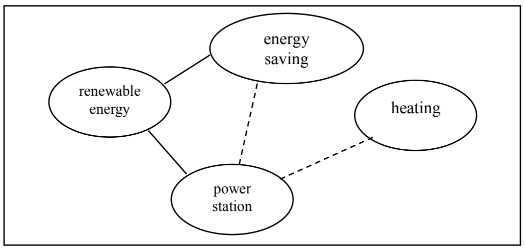

Figure 2. 7th graders' conceptual network related to stimulus words

In terms of the differences between 4th and 7th graders, the difference in knowledge in the given topic between the two age groups becomes conspicuous. While there is one more connection (5 altogether) in the group of 4th graders, all of them fall within the weak category. In 7th grade there are a relatedness of renewable energy and power station and a medium strength relatedness between energy and energy saving. The reason for the difference between the two age groups is assumed to be the following: while the ratio of concepts of everyday life and related knowledge (e.g. heating) is greater than that of scientific concepts in the conceptual system of younger learners (4th graders), (or rather, they tend to use everyday language to formulate their conceptual knowledge), their 7th-grade counterparts exhibit several well-related scientific concepts that enhance the strength of relatedness between stimulus words (due to more abstract thinking and the formal operational stage of cognitive development).

Table 5. Distribution of relationships of various strengths across stimulus words in the two age groups

	Strong		Moderately strong		Weak		Total	
	7th grade	4th grade	7th grade	4th grade	7th grade	4th grade	7th grade	4th grade
City	1	-	1	-	2	5	4	5
Village	-	-	1	-	1	3	2	3
Boys	1	-	1	-	1	2	3	2
Girls	-	-	-	-	1	3	1	3

Among the influencing factors we examined the differences between city and village students in terms of strength and quantity of relatedness between the stimulus words (Table 5). Thus it is clear that city learners outdo their village counterparts in both age groups both from a qualitative and a quantitative point of view in terms of their knowledge of the concepts that we studied on renewable energy. This can likely be attributed to the difference in the learners' levels of education (infrastructure, teaching methods applied, etc.) in city and village schools as well as to differences in the social backgrounds of the learners in the two types of settlements. As surmounting village students' disadvantages is a very important endeavour, finding the causes of the above differences requires further investigation. Across genders, the greatest number of relationships between stimulus words occurred in the boys' thinking in 7th grade, whereas in 4th grade it was the girls who produced the most such relationships. From a quantitative point of view, this is not a significant difference,

Relationships between stimulus words and associations

Conceptual networks are a good reflection of the strength of relatedness between the studied stimulus words, however, from the aspect of our investigation, it is more interesting to see the associations through which these concepts are linked to one another. By examining this question we can obtain an answer to the question: *what conclusions can be drawn about the strength, quality and nature of the relatedness of the stimulus words and their associated concepts?* To demonstrate this, we calculated the relative frequency of associations provided for every stimulus for both grades. We constructed the conceptual networks based on the relative frequency values presented in Table 6 (Kluknavszky & Tóth, 2009). The strongest relatedness values represent a relative frequency of 76% or over of all associations. We decreased this value by 15% at a time. Due to the great number of connections and their poor relatedness strength relative to the others we did not represent the lowest 15% in the conceptual map. Thus the associations occurring in the conceptual networks represent the most frequent concepts related to stimulus words that also constitute part of students' permanent knowledge on a topic. It is these concepts, too, that represent the nodes of the survey on environmental attitudes around which the questionnaire's statements can later be organised.

Table 6. Strength and notation of relative frequencies in the conceptual network containing associations

Relative frequency of associations	Strength of the relatedness	Notation
below 0-15 %	very weak	not presented graphically
16-30 %	weak	
31-45 %	medium	
46-60 %	medium strength	
61-75 %	strong	
over 76 %	very strong	

After calculating the relative frequencies of the associations provided by the students for 4th and 7th grades, we constructed association maps. We could clearly see (Figures 3 and 4) the predictable picture that 4th graders possessed fewer associations and relationships in accordance with the level of their cognitive development and knowledge. With 4th graders the strength of the associations related to the stimulus word power station failed to reach the relative frequency of 16%, necessary to be represented on a chart. This led us to conclude that the concept of power station has not yet become incorporated into 4th graders' conceptual system with proper efficiency. In contrast, 7th graders seemed to possess more comprehensive knowledge and signalled points of connection also between stimulus words that were closely linked to one another. In terms of strength of associations, the stimulus word 'heating' deserves mention in both grades - it is apparent that students can build the strongest associations with heating that is present in their everyday lives. The results connected to heating presumably suggest that students' experience derived from everyday life has a stronger influence on their environmental awareness. including their energy awareness, than their knowledge learnt formally at school as subjects.

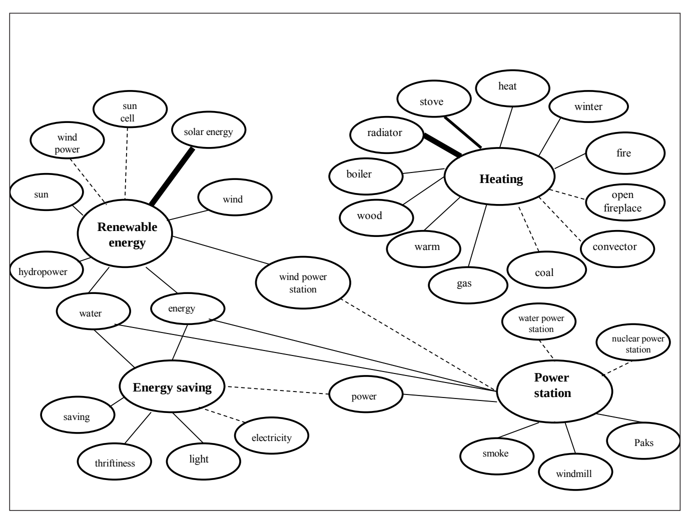

Figure 3. 4th graders' conceptual network in view of the relative frequencies of the associated concepts

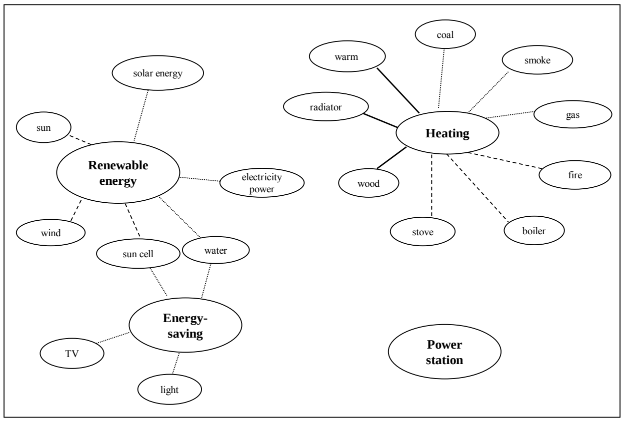

Figure 4. 7th graders' conceptual network in view of the relative frequencies of the associated concepts) (comment: Paks is a city in Hungary with a nuclear power station)

In terms of the number of associations there was a preponderance from learners living in big cities compared to those living in villages – the possible reasons for this have been mentioned before in connection with stimulus words.

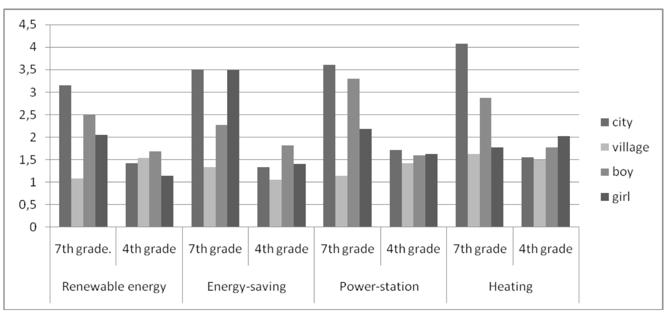

Figure 5. Relative frequency of the types of associations related to various stimulus words in 4th and 7th grades

We examined the number of different types of concepts provided by the students for the various stimulus words (Figure 5, Table 7). In terms of the relative frequency of the produced association types there was a significant difference between 4th and 7th graders as well as city versus village 7th graders for each stimulus word. At the same time, there was no significant difference between the numbers of association types of 7th and 4th graders living in villages. In terms of gender, 7th grade girls mentioned significantly more concepts for the stimulus word energy efficiency while 7th grader boys provided more associations for the stimulus words power station and heating. The advantage shown by 7th graders regarding the influencing factors can be observed here, too, and can be attributed, also in this case, to these students' more advanced cognitive develeopment and prior knowledge.

Table 7. Significance of differences between the frequencies of occurrence of the association types produced for stimulus words(n: all association types produced)

	Renewable energy (n=198)		**Energy-saving (n=176)**		**Power-station (n= 238)**		**Heating (n=228)**	
	7th grade (n = 198)	4th grade (n =142)	7th grade (n = 176)	4th grade (n = 123)	7th grade (n = 224)	4th grade (n =132)	7th grade (n = 187)	4th grade (n = 156)
City-village	t=10,58 p=0,000		t= 12,18 p=0,000		t= 9, 43 p=0,000		t=4, 39 p=0,000	t=4, 76 p=0,000
Gen der			t=8,45 p=0,013		t=10,24 p=0,004		t=3,34 p=0,021	

We also evaluated the association types from the aspect of the total number of times they were mentioned (Table 8). We found significant differences in terms of the relative frequencies of mentions of the associations between 7th and 4th graders for each stimulus word. These results also revealed the advantage of learners from cities due to reasons described above. In the field of mentions of all associations it was only with the stimulus word power station that boys produced more related concepts than did girls compared with types.

Table 8. Significance of the differences between the relative frequencies of the association types of mentions

	Renewable energy (n=981)		Energy-saving (n=809)		Power-station (n=955)		Heating (n=1527)	
	7th grade (n = 586)	4th grade (n = 395)	7th grade (n = 579)	4th grade (n = 230)	7th grade (n = 656)	4th grade (n =299)	7th grade (n = 892)	4th grade (n = 625)
City-village	t=11,29 p=0,000		t= 6,25 p=0,000		t= 11,84 p=0,000		t=5,54 p=0,000	t= 3,14 p=0,002
Gen der						t=2,38 p=0,01		

Based on the associations studied, in the given age groups, we observed the formation of the circle of common concepts that occurred most frequently in relation to renewable energy and that were part of the students' prior knowledge. These shared concepts could later provide the basis for a questionnaire for an environmental attitudes study in the given topic. These concepts are water, wind, sun, power station, sun cell, solar power, wind power, efficiency, electricity, and lamp.

Our research has given a picture of the studied population's knowledge structure for renewable energy, the quantitative and qualitative features of the concepts related to the topic and their network. Application of the free word association method also revealed concepts and interrelationships that we could not have gained information about from the closed and open-ended assignments of usual performance assessment batteries. Our evaluation has also shown what sources learners' topic-related knowledge comes from, and what the role of the school and everyday experience is in shaping any given knowledge. From this we can draw methodological conclusions, too, including the fact that, in the process of learning about things, it is necessary to map learners' prior knowledge that comes from everyday practice and incorporate it into their knowledge acquired during their school education. All this is signalled visually by the method of word association through the use of conceptual maps, which provides a clearer, more intelligible picture of leaners' knowledge compared with traditional evaluation. One advantage of the method is that data recording takes place quickly, within a couple of minutes, however, processing the data is time-intensive, making it favourable for processing small sample sizes. The analysis presented here is an evaluation procedure recommended for researchers, scientifically encouraged in its entirety and form. However, since a single association map can provide us with information (e.g., structure of the given concept, the relationship between the elements of a concept, level of understanding of a concept, its place in learners' knowledge, deficiencies related to a concept, possible misconceptions, conclusions for teaching methodology resulting from deficiencies) which would hardly, or not at all, emerge from traditional performance assessment, it is advisable for teachers to perform the method of assessment in a rationalised, less time-consuming way. For a teacher the more informative part of this evaluation is the map that also contains associations since it contains the interconnectedness among the stimulus words, too, and shows what associations lead to these connections. This is not shown by the map illustrating only the relationship between the stimulus words. The association map also reveals the most frequent concepts related to the stimulus words, again not shown on the map of stimulus words. This is why teachers do not need to get involved in time-consuming calculations of relatedness coefficients. Instead, they should enter the association types produced by the learners into an excel table (if a student has mentioned the association in question, they are given a 1). Then,then, using the excel programme's relevant function, teachers quickly calculate the relative frequency of each association and construct the association map based on the above value limits. Because the word association method does not reveal how a student defines a concept it is recommended that the method should be used in combination with the relevant assignments and evaluations of the traditional performance assessment.

CONCLUSIONS

The main purpose of the study was to desrcribe the application of the free word association method in the analysis of learners' knowledge structure. The topic we chose for our analysis was 4th and 7th graders' conceptual systems related to the concept of renewable energy, which we evaluated from the aspect of the role of age as well as of gender and size of settlement. The word association test has helped in demonstrating that, as learners age, their knowledge turns into a more and more complex structure comprising of more and more concepts and connections in the given topic. In terms of settlement size, the knowledge of city children proved to be more complex, which can presumably be attributed to the difference in the learners' cultural and social background as well as the more favourable infrastrucure and teaching methodology applied in city schools. In our analysis we first constructed the network of connections among the stimulus words followed by the descripiton of the relationship between the stimulus words and the associations attached to them as well as the quantitative and qualitative characteristics of the associations. We concluded here, too. that the word association method is descriptive, simultaneously giving a good overview of students' knowledge structure, and its quantitative and qualitative aspects. However, it is time-intensive and hence should be applied on small sample sizes. Yet, due to its informative character, it can be recommended as a method of evaluation to teachers, too, who can use it at school to assess students' current knowledge or the changes in that knowledge. To teachers we recommend a simplified, less time-intensive version of the free word association test, which considers only the analysis of the associations and the connection between the stimulus words and the associations. In this case the maps containing the associations simultaneously make clear the strength and nature of the connections between the stimulus words, too. Thus the word association test can complement the traditional, descriptive statistical analysis of school evaluation.

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Received 16-09-2016 /Approved 15-05-2017

Misconceptions sequencing the chemical processes in Daniell and electrolysis cells amongst first-year science and mathematics education university students

Conceptos alternativos de los estudiantes sobre los procesos químicos en las células de Daniell y de electrólisis

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Abstract

This study aims to analyse a number of misconceptions amongst first-year students from the Department of Mathematics and Science Education, Academic Year 2013/2014, at the University of Tadulako, Indonesia. The purpose is to explore the students' understanding of the concepts and the processes involved in electrolysis cells. In addition, the use and purpose of a salt bridge in these cells are also considered. A two-part test instrument was used to obtain the data. The test instrument involved a paper for the students to answer. The paper encompassed a series of stages for the mechanisms and processes that take place in (i) the Daniell cell (Zn-Cu) and (ii) the electrolysis cell for molten NaCl. Both processes were summarised into seven stages. Each stage consisted of three scientific illustrations for the students to choose from, with only one considered to be chemically correct. In addition, the students were asked to give a brief description of the mechanism they thought occurred at each stage and why. The results demonstrated that there was a higher level of misconception within the students' understanding of the electrolysis cell of molten NaCl (44%) when compared to their understanding of the Daniell cell (31%). For the Daniell cell, the half-reduction reaction (51%) was the most common misconception amongst the students, whilst for the molten NaCl cell ion migration (65%) appeared to be so.

Key words: *misconceptions, chemistry learning, Daniell cell, electrochemistry, electrolysis cell, molten NaCl, salt bridge.*

Resumen

Este estudio tiene como objetivo analizar una serie de conceptos erróneos entre los estudiantes de primer año del Departamento de Matemáticas y Educación Científica, (2013/2014), en la Universidad de Tadulako, Indonesia. El propósito es explorar la comprensión en los estudiantes de los conceptos y los procesos involucrados en las células de electrólisis y además, el uso y propósito de un puente de sal en estas células, también. Se utilizó un instrumento de prueba de dos partes para obtener los datos. Se hicieron una serie de pasos para determinar los procesos en la célula de Daniell (Zn-Cu) y la célula de electrólisis con el NaCl, fundido. Ambos procesos se resumieron en siete etapas, cada una consistió en tres ilustraciones científicas para los estudiantes, a elegir. Además, se pidió a los estudiantes que proporcionaran una breve descripción del mecanismo que pensaban que había ocurrido en cada etapa y por qué. Los resultados demostraron que había un mayor nivel de concepción errónea dentro de la comprensión de los estudiantes de la célula de electrólisis de NaCl, fundido (44%) en comparación con su comprensión de la célula de Daniell (31%). Para la célula de Daniell, la semireacción de la reducción era el error más común entre los estudiantes.

Palabras clave: *conceptos alternativos, aprendizaje de la química, célula de Daniell, célula de electrólisis, NaCl fundido, puente salino.*

INTRODUCTION

Studies on misconceptions of electrochemical cells have attracted the interest of a number of researchers and educators over the years (Barral, Fernández, and Otero, 1992; Ceyhun andKaragölge, 2005; De Jong, Acampo, and Verdonk, 1995; Garnett, Garnett, and Treagust, 1990; Nakhleh, 1992; Ogude andBradley, 1994; Sanger andGreenbowe, 1997b; Schmidt, Marohn, and Harrison, 2007). The subject of electrochemistry has long been regarded as something that is difficult to understand either by high school students and/or teachers (Davies, 1991; De Jong andTreagust, 2002; Griffiths, 1994; Johnstone, 1983). In particular, high school students reinforce that the conceptual understanding within the Daniell cell (Figure 1) and the electrolytic cell of molten NaCl (Figure 2) are of particular concern (Okpala andOnocha, 1988). It was proposed by Butts and Smith (1987) and supported by Garnett and Treagust (1992) that this may be due to the abstract concepts of electrolysis in general. Hence, the overall understanding of the processes involved in the cell is preventing the students writing the oxidation-reduction reactions correctly. This opinion was supported by a study in high schools in Nigeria which reported that more than 50% of grade XII students (age range from 16 to 20) considered that the concept of electrolysis was one of the most difficult concepts in science (Okpala andOnocha, 1988). This is plausible due to the abstract nature of the chemical concepts associated with electrochemical cells according to Huddle, White, and Rogers (2000).

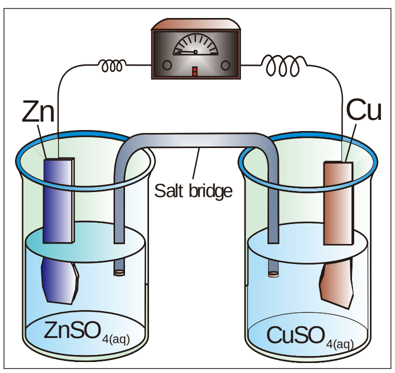

Figure 1. Illustration for the Daniell Cell (Spencer et al., 2010).

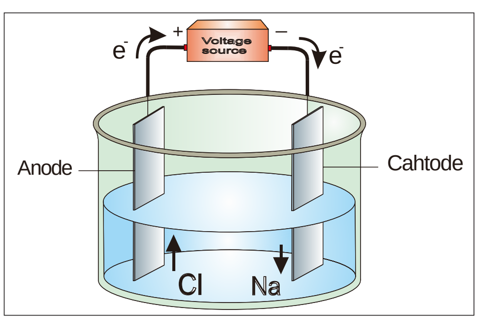

Figure 2. Illustration for the molten NaCl cell (Reger et al., 2009).
Figures 1 (Spencer, Bodner, and Rickard, 2010)
Figure 2 (Reger, Goode, and Ball, 2009)

It is apparent that the electrochemical misconceptions that first-year mathematics and science students possess can hinder the assimilation of new conceptual understanding as they progress through their studies (Sanger andGreenbowe, 1997a). A number of authors have tried to address these misconceptions by focusing on the barriers to learning by using computer animations (Andersson, 1986; Greenbowe, 1994; Niaz, 2002; Sanger andGreenbowe, 2000) and modelling (Huddle et al., 2000) to support conceptual understanding. Some authors have introduced various methods of measuring the misconceptions held by their students. For example, Hasan, Bagayoko, and Kelley (1999) applied a CRI (certainty, response, index) method; Treagust (1988) and Loh, Subramaniam, and Tan (2014) proposed a diagnostic test; and finally Brandt et al. (2001) and Kose (2008) utilized concept mapping and drawings to ascertain their students' understanding.

There are many different known electrochemical cells discussed in the literature for example; the Clark cell (Zn-Hg system); the De La Rue cell (Zn-Ag system); the Helmholtz cell (Zn-Hg system); the Guoy cell (Zn-Hg system); the Weston cell (Cd-Hg system) and finally the Daniell cell (Zn-Cu system) (Hamer, 1965). The electrolysis of molten or fused sodium chloride was first introduced in a Downs cell early in the last century (Downs, 1924). Subsequently, together with the Daniell cell (Boulabiar, Bouraoui, Chastrette, and Abderrabba, 2004), they both became an important feature in key physics and chemistry texts of the time.

Most teachers and educators often deliver both of these topics in the context of the electrochemical series, using very similar diagrams to Figures 1 and 2. They often treat the chemical theory as a whole process and they do not discuss each chemical transition as a separate stage. This often leaves the students' self-constructing the concepts and compounding their already developed misconceptions (Walanda andNapitupulu, 2013).

This paper aims to investigate the misconceptions that first-year undergraduate students from the Department of Mathematics and Science at the University of Tadulako, have on their conceptual understanding of the processes within an electrochemical cell.

METHODOLOGY

The study was introduced to a group of the first year Mathematics and Science Education Department students (n=184) at the University of Tadulako, Indonesia in the academic year 2013/2014 (see Table 1**)**.

Table 1
Summary table of the cohort of students in this study.

Program Study	Male	Female	Total
Mathematics Education	11	32	43
Chemistry Education	9	41	50
Biology Education	8	36	44
Physics Education	17	30	47
			184

All the students were registered on a course in basic chemistry subject knowledge and they all had previously been taught the theory within electrochemical cells in their last year of high school, including both the Daniell and the molten NaCl electrolysis cells.

The diagnostic test instrument utilized had previously been trialled with high school students (Walanda andNapitupulu, 2013),the results of which informed the final version of the test instrument that was used here. The first section of the test instrument was devoted to the Daniell cell and focussed on examining the sequence of mechanisms involved within the cell; whilst the second section reinforced the same but in the context of an electrolysis cell (molten NaCl). The tests were designed to explore the students' thorough understanding of the chemical concepts within each cell. This was done by summarizing the electrochemical concepts independently for both cells into seven stages. For each stage of the chemical process, the students could choose one of the three illustrations that had been suggested; only one of these was correct for each stage. Once the students had made their choice for each stage of the process they were then asked to articulate a brief description quantifying their choice, based on their chemical knowledge and understanding. In addition, they were also asked to articulate at what stage a salt bridge should be introduced in the Daniell cell to ensure the process was sustainable. The data collected from this study was then analysed using a data processing program (MS Excel).

RESULTS AND DISCUSSION

Figure 3 illustrates the percentage of student response for each stage of the Daniell cell, whilst Figure 4 demonstrates the percentage of student response for the electrolysis of molten NaCl (for both of these the dark grey bar indicates the correct choice). For the Daniell cell (Figure 3 and Table 2) it is evident that a vast majority of students understand two of the stages really well, matching the electrodes and electrolyte (94%) and the ion majority contained in each cell (97%). However, there were still challenges in the students' conceptual understanding of oxidation (49%) and reduction half-reactions (51%) as well as the role of the salt bridge in the cell (57%). It appears that the students' understanding of the electrolysis of molten NaCl (Figure 4 and Table 3), held more misconceptions than the Daniell cell. The students had good knowledge and understanding of the movement of the ions (73%) and the charge at the electrode (68%), although they had difficulty with the phase of the electrolyte (65%) and ion migration (53%).

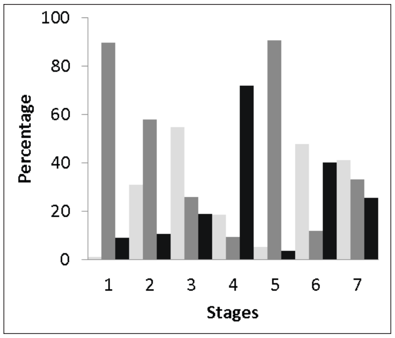

Figure 3. Graph summarising the percentage of student choices on the mechanism for each stage in the Daniell cell (choice I, choice II and choice III; dark grey bar indicates the correct response for the stage).

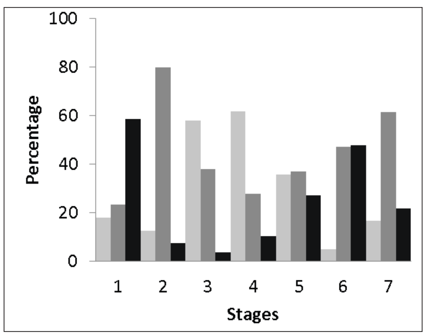

Figure 4. Graph summarising the percentage of student choices on the mechanism for each stage in the molten NaCl electrolysis cell.

Based on the data presented in Tables 2 and 3, it is evident that students have clear misconceptions in sequencing the mechanistic stages for both of the electrochemical cells studied, but especially the molten NaCl cell. This demonstrates that the chemical concepts that are used in the electrolysis cell are still poorly understood by the majority of the students. The concept of the ions migrating in the molten NaCl cell was perceived as a misconception by 53% of students. This reinforces that students still do not have a fully developed conceptual understanding regarding the movement and consequently the migration of the ions once the electrodes have been 'dipped' into the molten NaCl.

Table 2. Summary of misconceptions held by the students when questioned about their understanding of the chemical stages in the Daniell cell.

Stage	Concepts	Percentage with Misconceptions
1	Matching Electrode and electrolyte	6
2	Oxidation half-reaction	49
3	Reduction half-reaction	51
4	Metallic Conduction	18
5	Cations or Anions Dominance	3
6	The role of Salt Bridge	57
7	The net cell reaction	35
Average		31

Table 3. Summary of misconceptions held by the students when questioned about their understanding of the chemical stages in the electrolysis of molten NaCl.

Stage	Concepts	Percentage with a Misconception
1	Phase of Electrolyte	65
2	Ion Movement	27
3	Electricity/ion Source	43
4	Ion Migration	53
5	Electrolyte conduction	37
6	Electrode Charge	32
7	The net cell reaction	52
Average		44

In the Daniell cell, it is obvious that a large percentage of students had misconceptions regarding the concept of the reduction half-reaction (51%) and the use of a salt bridge (57%). The individual half-reactions in the Daniell cell are as follows:

$$\text{Cathode: } Cu^{2+}_{(aq)} + 2e \rightarrow Cu_{(s)} \qquad (1)$$

$$\text{Anode: } Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e \qquad (2)$$

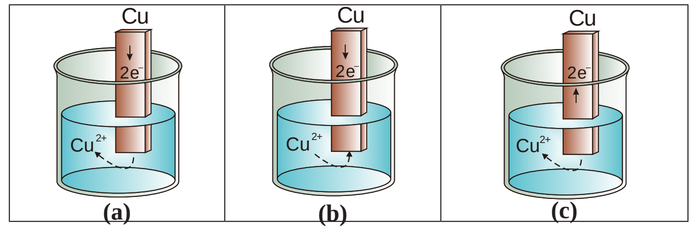

Figure 5. An illustration from the diagnostic testing tool used to ascertain students understanding in stage 5 the chemical processes of the Daniell cell.

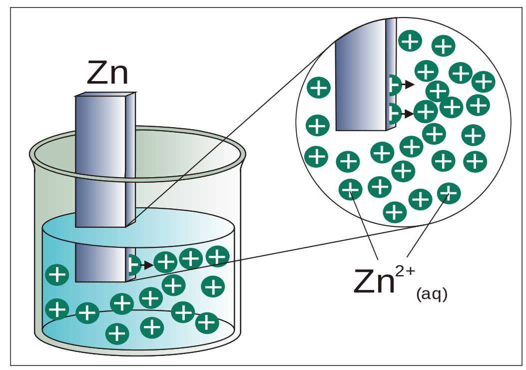

Figure 6. An illustration of the proposal for the reasoning behind the reaction stopping prior to a salt bridge being included.

Figure 5 illustrates part of the diagnostic test that was used to elicit students' understanding of the third stage in the seven mechanistic stages of the above reactions. Two of the options here show the movement of ions towards the solution thus distracting the students from the true conceptual understanding. The equation for the reduction half-reaction above demonstrates that there is a change in the phase of the Cu ions from dissolved in a solution into a solid, by consuming twice their number of electrons. Review of the diagnostic test given to students reinforced that generally they could write the above reduction reaction correctly. Thus, it is evident that the students have a good understanding about writing the redox equations for these types of reactions, but their understanding falters when abstract/diagrammatic representation is used to portray the concept. Hence, they all could not interpret the stages successfully when the abstract images/diagrams were used, and must, therefore, have gaps in their knowledge and understanding when challenged with the separate stages in these systems.

The function of the salt bridge in the Daniell cell is to support the process within the cell, to ensure the reaction is maintained over time. In the case of this cell, the oxidation half-reaction is the first chemical stage of the processes involved in the redox reactions that subsequently take place. Figure 6 illustrates a proposal for how the saturation of positive charge from the Zn^{2+} ions acts as a barrier for the continuation of the reaction if current cannot flow through the cell (The Zn reaches an equilibrium with the solution). If this proposal is true, it offers an explanation for the prevention of the further oxidation of the Zn metal. If this does happen the electrons that are sourcing the reduction reaction are now not available and overall this results in no electrons flowing from the zinc electrode to the copper electrode, which in turn results in no electricity flowing between these cells. This problem is overcome by placing a salt bridge that connects the two individual half-cells. The salt bridge's main function is to maintain the balance of electrical charge across the two half-cells. It often contains an inert concentrated salt (such as KCl or KNO_3) mixed with a gel.

The findings from the diagnostic tests indicate that there are misconceptions from the students in determining what stage the salt bridge is introduced to the system. There was great disparity between the students' responses here. A third (34%) indicated that the salt bridge was introduced in the early stages. An explanation for this could be due to them being provided with diagrams of this nature in high school, prior to undertaking a practical activity based on redox. A higher proportion of students (49%) indicated that the salt bridge was introduced in the fifth stage of the seven concepts proposed. There were also some students who answered that the function of the salt bridge was to act as a medium for ions (sulfate and zinc) to move between each half-cell. This indicates that the students contextualised the salt bridge's function to the purpose of a physical bridge, in terms of mediating the transfer of an object from one side to the other. When the students were questioned why the half-oxidation process ultimately stops, there was definite gender split from the responses. Very few male students could articulate a reason for this, whilst the female students deduced that the copper electrode had been covered with newly formed copper. When this point was explored with the female students, there was a realisation that the 'new' copper would react exactly the same as the 'old' copper and that their response was indeed not plausible.

The movement of ions contained in the salt bridge ensured that there was a continuous flow of electrons between the two half-cells. The negative ions of the salt bridge (such as iodide or nitrate ions) will migrate to the aqueous half-cell which is dominated by the positive charge due to the electrostatic attraction of oppositely charged ions i.e. the Zn^{2+} ions. In contrast the positive potassium ions will migrate to the aqueous half-cell which is dominated by the negatively charged species, the sulfate ions. In the Zn half-cell, which was initially dominated by aqueous Zn^{2+} ions, further electrons will now be produced ensuring a constant flow of electrons through the external wire to the copper electrode. With the presence of an electron flow it would mean that the Daniell cells' half-reactions will be continuous once more.

CONCLUSIONS

Diagnostic test instruments using illustrations of chemical processes have detected misconceptions amongst first-year mathematics and science students in sequencing the mechanism stages occurring in the Daniell cell and the molten NaCl cell. For the Daniell cell, the half-reduction reaction is considered as the most problematic misconception amongst the students, whilst ion migration in the electrolyte, is the most common concept detected as a misconception in the molten NaCl cell. Before a student can fully understand the seven stages identified for each electrolytic cell discussed in this paper, there needs to be a clear foundation of knowledge and understanding built upon the key prior principles of electrolysis. This needs addressing with the students before their transition to University to ensure they make the required progress with this subject and, to as much as possible, eradicate the misconceptions identified here.

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Received 16-09-2016 / Approved 15-05-2017

Fractal approach to teaching physics and computer modeling
Enfoque del fractal en la enseñanza de la física y modelizacion por computadora

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Abstract

The article presents and appraises the fractal approach to teaching physics using computer modeling in the environment of the object-oriented programming. It manifests the formation of a fractal structure and the corresponding iteration, reflecting the integrity and spontaneity of information perception. The article elaborates the iteration of the fractal structure on the example of studying physics topics, "Geometric optics" and "Wave optics". Each iteration (section of physics) is characterized by a synergy - adding new iteration provides a qualitative perception of the information. The possibility of using this approach in other physics topics and research fields related to physics has been demonstrated.

Key words*: computer modeling, fractal approach, self-organizing processes, synergetic, teaching physics.*

Resumen

El artículo presenta el enfoque de fractales en la enseñanza de la física mediante la modelización informática en el entorno de la programación orientada a objetos. Manifiesta la formación de una estructura fractal y la iteración correspondiente, reflejando la integridad y espontaneidad de la percepción de la información. El artículo elabora la iteración de la estructura fractal en el ejemplo de estudiar secciones de física, «Óptica geométrica» y «Óptica de onda». Cada iteración (sección de física) se caracteriza por una sinergia - la adición de una nueva iteración proporciona una percepción cualitativa de la información. Se ha demostrado la posibilidad de utilizar este enfoque en otras secciones de la física y campos de investigación relacionados con la física.

Palabras clave*: modelización informática, enfoque fractal, procesos autoorganizadores, sinergética, enseñanza de la física*

INTRODUCTION

Innovative teaching of physics and computer modeling of physical phenomena, as well as the application of these methods by teachers, are the focus of special attention in scientific literature (Christian & Esquembre, 2007; Potter & Peck,1989; Sladek, Pawera & Valek, 2011). However, special training of future physics teachers on numerical modeling of physical phenomena, bibliographic data in the pedagogical literature, as well as in educational practice are encountered less often. For example, the curriculum of training future teachers of physics in all five Slovakian universities does not contain this subject. Students and future teachers can get acquainted with the problem of computer modeling of physical phenomena while studying special subjects such as "Digital technologies in teaching physics", "Computer Information Technologies in physics" (http://www.fpv.umb.sk/katedry/katedra-fyziky/studium/bakalarske-studium/). A similar situation with mastering these methods is observed in other universities.

In the process of teaching physics, attention is focused on a significant amount of material and its unstructured character (Özcan, 2015; Hodson, 2014; De Cock, 2012; Fojtík, 2013), insufficient relationship and correlation with other disciplines (Hestenes, 2010; Huffman, 1997) and practical application (Reif & Heller, 1982). It points to the need for information perception in higher educational establishments, especially in teaching physics at an intuitive level, using visualization means, modern advances in programming – object-oriented programming.

The aim of the investigation was the implementation of the educational experiment based on the positive impact of the applied measures aimed at creating the optimal objective of professional competence of future physics teachers. The study objective was to determine the impact of implementing innovative approaches on the willingness and interest of future physics teachers to independently conduct computer simulations of physical phenomena.

METHODOLOGY

There is a relationship between the different branches of physics and among its various sections that can be demonstrated using a fractal approach (Mar'yan & Yurkovych, 2015). This means that in teaching one of the sections (subsections), an algorithm can be determined that is produced and realized in the following sections and, thus, a complex structure is formed while maintaining the integrity of material perception using computer modeling. This approach is tested in teaching electromagnetic phenomena in the sections of physics, "geometrical optics," and "wave optics."

A fractal is a branched or dispersed structure, whose dimension is different from that of an integer (Falconer, 2003). There are geometric, algebraic and stochastic fractals (Frame & Mandelbrot, 2002), applied in various fields of physics in modeling of nonlinear processes, such as turbulent fluid flow, diffusion processes, plasma, porous materials (Shuster, 1984; Haken, 1985). One of the properties of fractals is self-similarity on spatial and temporal scales, which predetermines the usage of one algorithm in the formation of complex structures with a minimum dissipation of energy (Nicolis & Prigogin, 1989; Haken, 2006; Mar'yan & Yurkovych, 2015; Mar'yan & Yurkovych, 2016). This may be illustrated by the so-called Sierpinski carpet in Figure 1. The Sierpinski carpet is a line that has an infinite length and confines a finite area. This line is the self-similar, i.e., composed of three parts that are similar to the entire curve as a whole with the ratio of similarity one to two, and fractal dimension df=1.5849 (Falconer, 2003).

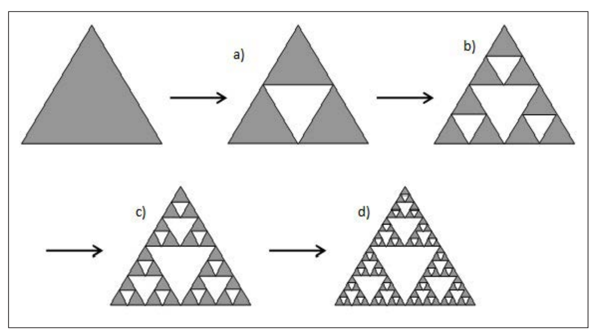

Figure 1: Fractal—the Sierpinski carpet (Falconer, 2003).

It applies the environment of the visual programming, Delphi, and the algorithmic programming language, Object Pascal, which is built on the principles of object-oriented programming and the latest information technologies—RAD (rapid application development), VCL (visual component library), DLL (dynamically linked libraries), OLE (object linking and embedding) (Bucknall, 2001).

The educational experiment involved students of two universities: Uzhgorod National University (Uzhgorod, Ukraine) and the University of Prešov (Prešov, Slovakia). Control groups consisted of 10-18 students. Upon the completion of the students' studies, the test control was conducted, which aimed to find out changes in the knowledge and skills of students after the implementation of the offered approach. A part of the test questions were aimed at ascertaining the interest of students towards the further study of computer modeling of physical phenomena.

RESULTS

Fractal structure. The first iteration.

The laws of reflection and refraction of light (the Law of Snelus). This is analogous to the first iteration of the fractal—the Sierpinski carpet in Figure 1a. The algorithm contains the features of computer modeling of the light propagation process at the interface of two environments, and is further used for the following phenomena (steps), forming a more complex but internally self-sufficient fractal structure.

After consideration of these laws in the environment of visual programming Delphi, the students create the interface (Figure 2): the following components are used (Bucknall, 2001). Students have the opportunity to directly modify the parameters of the optical system (angle of incidence α, refractive index n, the factors of reflectivity and diffuseness), means of visualization of the rays in Delphi environment (colors of the incident and reflected rays, types of lines) and become active self-sufficient participants in conducting computer experiment in Figure 2. It is important to develop the algorithm of information perception by students on the intuitive level that will be used and developed further in later iterations (lectures).

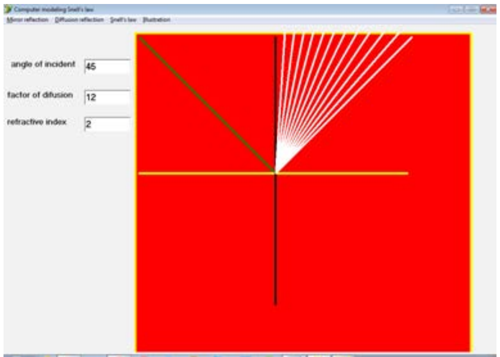

Figure 2: The visual interface of modeling the laws of light reflection and refraction in the Delphi environment.

The second iteration.

Total internal light reflection in Figure 3. This is analogous to the second iteration of the fractal—the Sierpinski carpet in Figure 1b. It is important to note that the formation of this and subsequent iterations retain the "algorithm" of the fractal structure incorporated for the previous iteration that ensures the integrity, self-sufficiency and localization of perception. It is important to use computer modeling (Gould & Tobochnik, 1988), which determines the cross-cutting nature and the spontaneity of the material presentation, the features of object-oriented programming languages developed on the principles of encapsulation, inheritance and polymorphism (Bucknall, 2001; Cantu, 2008). Because of this, each iteration makes use of the properties of the previous one, and, at the same time, it must contain new information (property, method)—in this case, the possibility of directional light propagation.

The illustration of the refraction laws and total internal reflection in Delphi environment are depicted in Figure 3. Students get the opportunity to change the parameters of the optical environments, to observe the ray propagation in real time under total internal reflection.

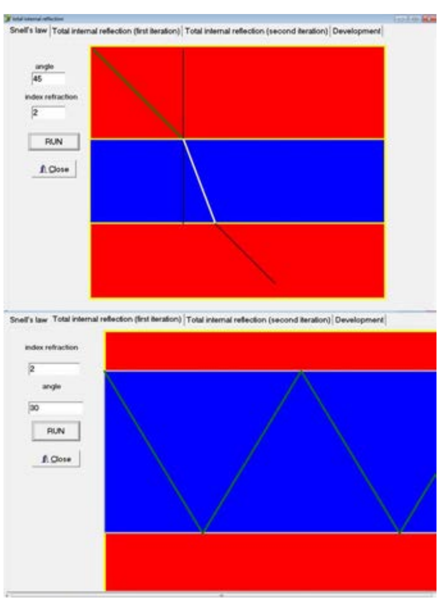

Figure 3: The visual interface of computer modeling of the total internal reflection phenomenon.

The third iteration.

Determination of light transmittance of a thin film taking into account multiple reflections and using the methods of approximation in Figure 4. It is analogous to the third iteration in Figure 1c.

Students are introduced to the concept of light absorption - the phenomenon of the reduction of light wave energy during its propagation in the substance as a result of converting wave energy into other forms of energy. To experimentally obtain dependences of transmittance upon the wavelength in the visible region of the spectrum, the students carried out the two-parametric approximation method (Hestenes, 2010). The two-parametric dependence has been considered: $y=ge^{mz}$, where *m,g* variational parameters which are determined in the process of computer modeling (Figure 4). The visual interface of the calculation program in Delphi environment is given in Figure 4. The qualitative difference of this iteration consists of introducing the analytical dependence and its graphical visualization. However, there remains the need inherent in previous iterations of structuring teaching material and enhancing students ' attention, involving them in the formation of the fractal structure (Mar'yan & Yurkovych, 2015).

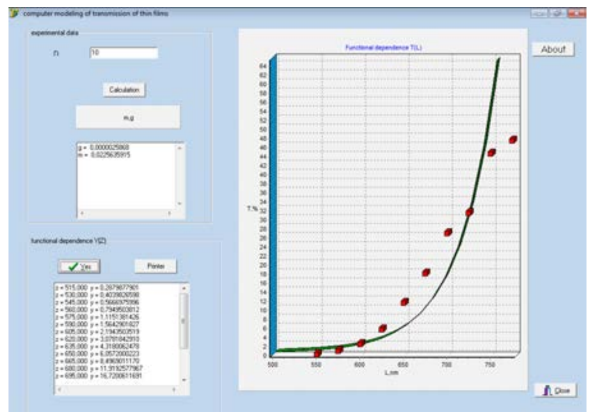

Figure 4: Visual interface of two parametric approximation of light transmittance in the Delphi environment.

The fourth iteration.

Modeling of the optical characteristics of the positive and negative lenses in Figure 5 is analogous to the fourth iteration in Figure 1d. In order to perform the fourth iteration of the fractal structure the students have been familiarized with some methods of determining the focal distances of converging lenses taking into account the position of the principal planes and the refractive index of the lens material.

The optical power of a thick lens can be calculated by the formula:

$$\Phi = \frac{1}{f'} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) + \frac{d(n-1)^2}{n \cdot R_1 R_2}$$

where f ' – the back focal distance of the lens, R_1 and R_2 – the radii of the refractive surfaces curvature, n - the refractive index of the lens material, d - the thickness of the lens.

In the process of using computer modeling (Gould & Tobochnik, 1988) there exists a significant contribution of graphical tools for data visualization (building various types of graphs for a single analytical dependence, that is, one and the same analytical dependence is observed by students at different visual foci) in Figure 5.

The fifth iteration.

Practical application of the given physical phenomena in Figure 6. It should be noted that the fractal structure has a fractional dimension, completely filling in the corresponding space (Mar'yan & Yurkovych, 2015). The practical application itself is analogous to the fifth iteration in Figure 1 and reproduces the integrity and development of the section of physics, "geometric optics." (Mar'yan, Kikineshy & Mishak, 1993; Mar'yan, Kurik, Kikineshy, Watson & Szasz, 1999; Young & Freedman, 2003).

To create the interface of the program in Figure 6, students were asked to use the object Image in Delphi environment. The students got acquainted with the technical product — optical fiber consisting of an optical fiber waveguide, protective coatings and marking colored membrane.

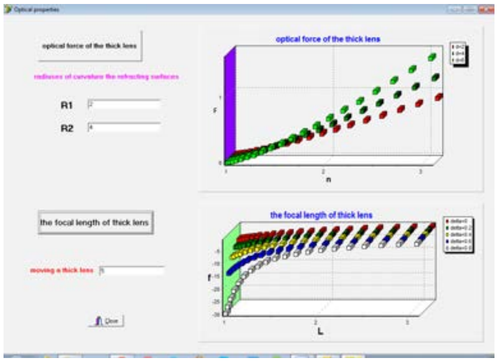

Figure 5: The visual interface of modeling optical parameters (optical power and focal distance) of a thick lens.

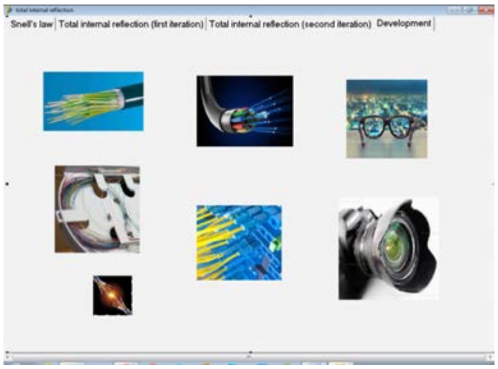

Figure 6: Practical use of the phenomenon of total internal reflection in fiber-optic communication lines and optical lenses.

Each iteration (section of physics) is characterized by a synergy - adding a new iteration provides a qualitative perception of the information (without an additional introduction of the division according to themes). This encourages the student to become an active participant (Haken, 2006; Mar'yan & Yurkovych, 2015). This synergy creates a unique fractal structure, capable of development and functioning (Mar'yan & Yurkovych, 2016).

The iteration discussed above can be complemented and developed, in particular by involvement of learning using the testing tools (Hodson, 2014), with the exchange of information using the Internet (De Cock, 2012), that is, the process generates and allows an infinite number of steps, which is essential for fractal structures (Frame & Mandelbrot, 2002).

Based on the presented approach of the joint synergistic usage of lectures on physics and computer modeling, the fractal structure (table 1) is formed on an intuitive level (Sherin, 2006). Functioning of this structure is manifested in the transition to students' self-sufficiency, involving the use of a creative approach and the desire to apply the obtained information in radically new areas (Young & Freedman, 2003). For example, the phenomenon of total internal reflection along with the classical perception of physics as a process of dissemination of information (informatics). Or, preparing a hamburger (cooking) as related to the Belousov-Zhabotinsky reaction with the formation of dissipative structures (chemistry), dancing rhythms (music).

Table 1. The formation of the fractal structure of information perception.

Steps	Levels of information perception
The first step	Physics
The second step	Physics and computer modeling
The third step	The intuitive perception of information by students and the formation of the fractal structure

The resulting fractal structure is qualitatively manifested in the table 2.

Table 2. Fractal structure in the study of physics sections "Geometric optics", "Wave optics".

Iterations	Objects
The first iteration	Computer modeling the laws of light reflection and refraction
The second iteration	Computer modeling the laws of light reflection and the total internal reflection phenomenon = { Synergy of integration in the Delphi environment }
The third iteration	Computer modeling the laws of light reflection, the total internal reflection phenomenon and two parametric approximation of light transmittance = { Synergy of integration in the Delphi environment }
The fourth iteration	Computer modeling the laws of light reflection, the total internal reflection phenomenon, two parametric approximation of light transmittance and the modeling optical parameters of a thick lens = {Synergy of integra-tion in the Delphi environment }
The fifth iteration	Computer modeling the laws of light reflection, the total internal reflection phenomenon, two parametric approximation of light transmittance, the modeling optical parameters of a thick lens and practical use of the phenomenon of total internal reflection in fiber-optic communication lines and optical lenses ={Synergy of integration in the Delphi environment}

DISCUSSION

Thus, a fractal structure in teaching one of the sections of physics, "geometrical optics," is formed (it can be easily spread to other branches of physics). The advantages of this approach are obvious: the corresponding physics section is perceived as a single unit without the mechanical separation into its component parts; and the possibility of forming branched structures according to a single algorithm that can be extended to other branches of physics, while maintaining the integrity (fractality) at the level of several sections (Breslyn & Mcginnis, 2012; Kuo, Hull, Gupta & Elby, 2013). The given approach is also used in the formation of a fractal structure, which is implemented, in particular, in the transition from geometrical to wave optics. Moreover, the iterations analyzed above, iterations 1–5 in Figure 2–6, are considered as the first iteration of a new fractal structure formation. It should be noted that unlike the classical approach, which is based on the assimilation of a certain amount of material (Özcan, 2015; Hodson, 2014), the fractal connections reflect the internal structure of the sections (Mar'yan & Yurkovych, 2015; Mar'yan & Yurkovych, 2016) that are assigned spontaneously. In computer modeling, along with the use of the algorithmic programming language, Object Pascal, other object-oriented languages such as C++, Java, and Ruby, can be used.

The offered fractal approach was tested in Uzhgorod National University (Ukraine) for students at the Faculty of Physics and the University of Prešov (Slovakia) for students of humanities and natural sciences at the Department of Physics, Mathematics and Technology. Unlike Slovakian universities which train physics teachers, Uzhgorod University has considerable experience in applying computer modeling of physical phenomena.

The study carried out the evaluation of the quality of training of the discipline "Programming and mathematical modeling" for students of physical faculty according to the specialization "physics teacher" (a group of students consisting of 16-18 people) in Uzhgorod National University during the period 2012/2013-2015/2016. Figure 7 manifests the diagram showing the dependence of the assessment rating for 2015/2016 academic year in the process of teaching material during 12 lessons (lessons included lectures and laboratory classes). We observe the growth of students' academic performance in mastering the discipline (assessment ratings are in the range of 82-89 B, 90-100 A), which is confirmed by the diagram in Figure 7. Students' activation point and deeper perception of the material are realized in the range of the 2nd-4th lessons (Figure 7, profound knowledge is gained 82-89, excellent marks are formed 90-100 A). Similar results were obtained for groups of students of this specialization, who studied in 2012 / 2013-2015 / 2016 (Figure 8 represents reduced ratings of the final assessment (final lesson 12, Figure 7)). That is, the obtained dependence in Figure 7 is not accidental; it is naturally manifested owing to the fractal approach of teaching physics processes during 4 years (Figure 8).

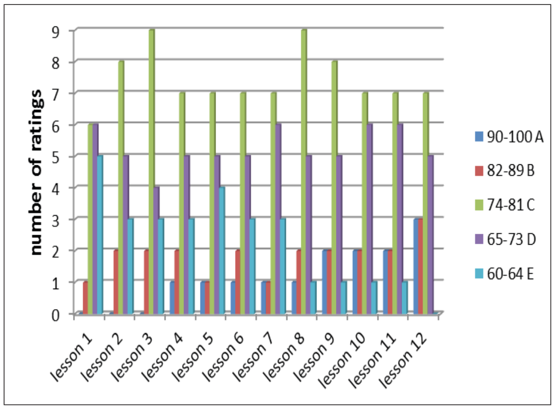

Figure 7: The diagram of the dependence of assessment ratings in 2015/2016 academic year

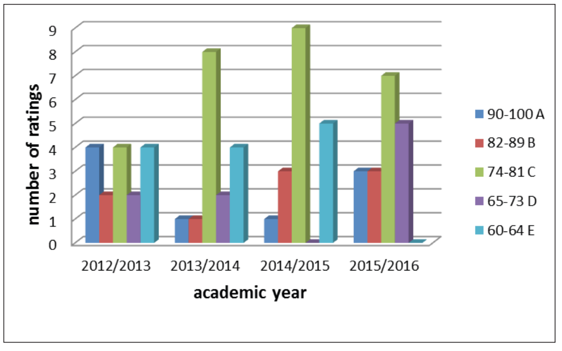

Figure 8: The diagram of academic performance in the study discipline "Programming and mathematical modeling" for 2012 / 2013-2015 / 2016 academic years

The research in Prešov University was conducted in 2015-2016 academic year. The experiment involved 10 students in the study subject "Methods of teaching physics" including computer modeling of physics sections "Geometrical optics", "Wave optics". The conducted rating control indicates the students' interest in computer simulation used in teaching physics in 93% of future physics teachers and the increase in their level of mastering material by 11%.

During these classes, the activation of students, and in-depth perception of the material have been noted. In our opinion, the adoption and usage of the methodological approach of modeling physical phenomena and processes by future teachers of physics is very useful (Windschitl, 2004). It creates space for the expansion and implementation of the key competencies in the area of targeted and effective use of information and communications technology in school physics experiments (Luft, 2001; Lotter, Harwood, & Bonner, 2007; Schwartz, & Lederman, 2008).

CONCLUSIONS

The fractal approach to teaching physics using computer modeling in object-oriented programming, Delphi, has been substantiated. The formation of a fractal structure has been established and the iteration has been determined, which reflect the integrity and spontaneity of presenting information. The application of fractal approach for students of the Physics Faculty in Uzhgorod National University in 2012 / 2013-2015 / 2016 academic years shows the increase in the level of academic performance by 28-30% (the increase in the number of students who received grades in the intervals of 82-89 B, 90-100 A) and the decrease by 30-34% in the number of students who received grades in the range of 60-64 E, 65-73 D.

The lectures for students of Prešov University in Slovakia with the use of a fractal approach in teaching physics sections "Geometric optics", "Wave optics", and computer modeling have been conducted. The rating control of interest level to teaching computer modeling for future physics teachers comprises 93%, and the academic performance has increased by 11%. The involvement of students of related majors in two universities - Uzhhorod and Prešov - demonstrates the feasibility of using fractal approach in preparing future teachers of physics in higher educational establishments.

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Received 17-11-2016 /Approved 15-05-2017

A student-generated less-familiar atomic orbitals (*l* = 4–10) representation using simple and real-time visualization software

La representación de los orbitales atómicos menos conocidos (*l* = 4-10) usando simple software de visualización

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Abstract

Hydrogen atomic orbitals generally introduced to chemistry students are restricted to s (l = 0), p (l = 1), d (l = 2), f (l = 3) orbitals. This way makes student wonder about what the post-f orbitals look like. The literature provides very little information on this. In this situation, teachers usually simply represent orbitals in Power Point slides or transparencies without involving students in constructing an orbital from its original equation. This work provides a simple way to real-time plotting of 105 lesser known atomic orbitals (l = 4–10) for learning projects in the classroom. Constructing orbitals on their own project allows students to become familiar with less well known orbital characteristics and their related equations.

Key words: *computer-based learning, atomic orbital, physical chemistry*

Resumen

Orbitales atómicos del hidrógeno introducidos generalmente a estudiantes de química están restringidos a s (l = 0), p (l = 1), d (l = 2), f (l = 3) orbitales. De esta manera hace que el estudiante pregunte acerca de lo que parecen los orbitarios después de f. La literatura proporciona muy poca información sobre esto. En esta situación, los profesores generalmente, simplemente representan orbitarios en diapositivas o transparencias sin que los estudiantes participen en la construcción de un orbital de la ecuación original. Este trabajo proporciona una forma sencilla de trazar en tiempo real de 105 orbitales atómicas menos conocidas (l = 4-10) para el aprendizaje de proyectos en el aula. Construir orbitales en su propio proyecto permite a los estudiantes familiarizarse con las características de orbitales y sus ecuaciones relacionadas.

Palabras clave: *aprendizaje asistido por computadora, orbital atómico, físicoquímica*

INTRODUCTION

One of the biggest challenge for chemistry teachers is how to teach an abstract concepts in chemistry to become a physically interpretable concept which has direct application in real life. Generally, teachers worry when teaching concepts such as atomic structure which have no direct link to real life and require spatial imagination (Finley et al., 1982; Tsaparlis, 1997; Niaz, 2002; Park & Light, 2009). Nevertheless, those topics should be taught because understanding of atomic structure has consequences for the way students understand chemistry (Taber, 2003).

The Indonesian ministry for education enacts concept mastery on atomic structure topics as a mandatoried competency standard for secondary chemistry students. The competency standard requires that the student is able to analyze the historical background of atomic model, the atomic structure based on Böhr and quantum mechanics theory, and the relationship between electron configuration and orbital diagram to determine the location of elements in the periodic table and periodic properties of elements (Indonesian Curriculum Standard for Secondary Education, 2013). However, there are several views on whether the quantum chemistry concepts is suitable for secondary and undergraduate students, although most of them agreed to teach it with some strategies than leave out (Tsaparlis, 1997; Budde et al., 2002; Tsaparlis & Papaphotis, 2002; Park & Light, 2009). In this case, even if teaching modern quantum chemistry concepts shows many barriers, they should be introduced, and they are necessary if it really needed, with great care (Tsaparlis, 1997; Tsaparlis & Papaphotis, 2002). For example, Polydoropoulos (1974) suggest the careful introduction of a mathematical function describing an electron in an atom or molecule and pictorial models must be built onto the mathematics to turn it into a useful intuitive tool (Tsaparlis & Papaphotis, 2002). Therefore, learning atomic structure should be designed more interactive, educative, and realistic so that students appreciate the importance of this topic.

Nowadays, teaching atomic structure theory is focused on Schrodingers' overviews which is the most accepted electronic structure theory. In principle, this theory applies Schrodingers' wave equation to explain entire electronic properties of molecules, and should be capable of describing all aspects of bonding. Moreover, learning modern atomic structure should introduce the ideas of an "orbital" as a core concept that represents the most probable volume in which an electron will be found. Teaching about orbitals is restricted to only *s, p, d, f* (*l* = 0–3) orbitals since this is sufficient to cover the electronic structure (ground state) of all elements in the Periodic Table. There is very little literature provided concerning the representation of post-*f* orbitals or help for teachers to deliver orbital concepts interactively. On this topic, physical chemistry teachers usually use traditional teaching strategies without allowing students to construct orbitals in their own projects. Those conditions potentially raise some disadvantages such as: (a) wrong interpretation that orbitals only exist for *l* = 0–3, (b) students' will not understand about how orbitals is constructed, post-*f* orbitals' characteristics, and "the components" determined orbital shapes and orientations. Thus, students' personal activities in constructing less familiar' orbitals ($l > 3$) could be quite important.

Students' projects in constructing orbitals can be effectively facilitated by applying graphical visualization tools. Producing orbital representation from its corresponding mathematical equation is believed to encourage students to understand equation-graph relationship and characteristics of the produced graph. Some researchers have reported the functionalities of mathematical softwares like Matlab (Shechter, 2016), Matcad (Ellison, 2004), Mathematica (Cooper & Casanova, 1991), Maple (Stewart, 2013), to visualize orbital. However, these applications are not suitable for beginners because they require special coding skills. Chung (2013) suggested a free-distributed software named Winplot (Parris, 2012) that is usable for beginners (without complicated scripting) and has applied this software to plot the shape of *s*, *p*, *d* atomic orbitals. Our previous study (Saputra, 2015) has also used this software to visualize three dimensional hybrid atomic orbitals. This recent study provides a strategy to create 105 lesser known atomic orbitals (*l* = 4-10) using Winplot. Constructing less familiar atomic orbitals in a student's own project is expected to enhance the student's understanding about post-*f* orbitals and actively participate in learning modern atomic structure.

RESULT AND DISCUSSION

Deriving the wave equation

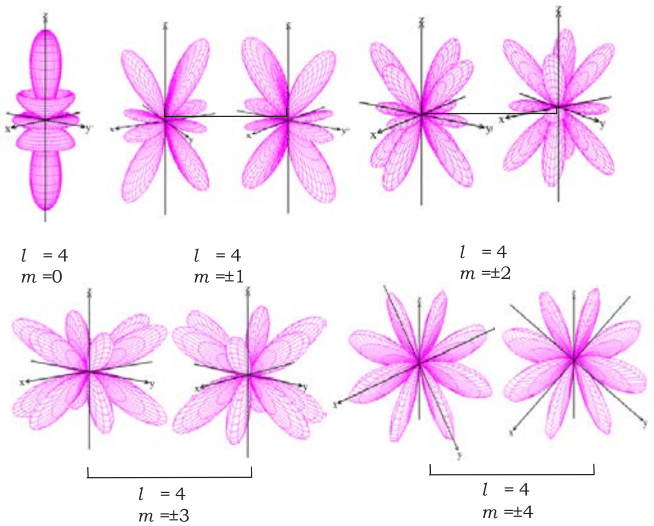
The Schrodinger wave function as generally known consists of radial $R(r)$ and angular $Y(\theta,\phi)$ components. By referring to many standard physical chemistry textbooks (McQuarrie, 1983; Atkins & Paula, 2010; Mortimer, 2008), anyone can understand that orbital shapes and orientations is only determined by the angular parts, whereas radial parts determines the size of orbital. The general equation for angular parts is shown in equation 1.

$$Y_{(\theta,\ \varphi)} = \left(\frac{2l + 1(l - |m|)!}{4\pi(l + |m|)!} \right)^{1/2} P_l^{|m|}(\cos\theta) e^{im\phi}$$

where $P_l^{|m|} = \frac{1}{2^l l!}\left(1 - x^2\right)^{\frac{|m|}{2}} \frac{d^{1+m}}{d^{\,l+m}x}\left(x^2 - 1\right)^l$ is associated Legendre function with *l* and *m* is azimuthal and magnetic quantum number, respectively (McQuarrie, 1983). The complete wave function and its corresponding winplot code can be provided in the Supporting Information (Please contact authors by email).

Visualizing non-famous orbitals

By simply converting the angular wave equations in table 1 to Winplot code as described by Chung (2013), one can visualize many types of less familiar atomic orbital representation. As example, representation of orbital for $l = 4$ is presented in figure 1.



CONCLUSIONS

A large set of less familiar atomic orbitals has been successfully generated by students using simple Winplot software. Applying Winplot makes students project to visualize orbital become simple and possible. Then, this powerful software is highly recommended to be used in teaching atomic structure in schools or universities.

ACKNOWLEDGMENTS

Authors declare many thanks to Mr. Fajar Arrasyid, Graduate Students' of Chemical Education, University of Lampung for their contribution in producing high quality orbital pictures in the manuscript.

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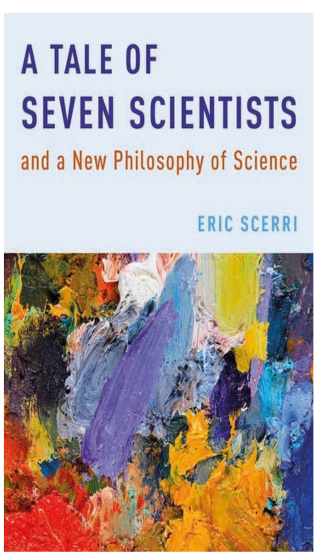
Received 6-04-2016 /Approved 15-05-2017

Books review

Eric R Scerri. A TALE OF SEVEN SCIENTISTS AND A NEW PHILOSOPHY OF SCIENCE. Published by Oxford University Press, 2016. ISBN: 9780190232993



This is an intriguing book that provides an extensive source of information about seven little-known chemists and their contribution the development of chemical ideas. It also pictures the nature of scientific development in ways that challenge our more usual views. The author perceives the progress of science to be much more an 'evolution to fit the environment' than a closer approach to the truth, snd ascribes value to 'wrong theories'.

In the preface to the book there are two perceptive forewords by Peter Atkins and by James Marcum and also, a fairly extensive autobiographical summary of the author's own professional growth as a chemist and philosopher of chemistry. This last provides a valuable insight for the reader into the possible sources of the 'new philosophy of science' that is presaged in the title of the book. Such a section should probably be mandatory in any publication in which new, and possibly controversial, ideas are being propounded.

The 'seven scientists' in the title are each provided a chapter within the main text and their names are John Nicholson; Anton Van den Broek; Richard Abegg; Charles Bury; John D Main Smith; Edmund Stoner and Charles Janet. The main chapter headings are reproduced below, together with a few comments in *italics.*

Chapter 1. Introduction: Intermediate historical figures & how can 'wrong theories' lead to scientific progress?

Chapter 2. The intriguing case of John Nicholson. *This provides examples of some very impressive results from a theory that turned out to have no foundations. It is argued that this work contributed significantly to the conclusions of Niels Bohr – despite being wrong. There seems to be a couple of typographical errors (e.g. in the text, 'c' is given for the speed of light whereas 'a' seem to be used for this within the equations on p16-17), but these are minor faults.*

Chapter 3 Van den Broek and atomic number. *A very good case is made for Van den Broek being the first to recognize the importance of atomic number – rather than atomic weight – in structuring the Periodic Table. I was also fascinated to read that since, within his calculations, hydrogen was anomalous he* ***omitted*** *it from his tables!*

Chapter 4: Richard Abegg, an early pioneer of chemical bonding. *Abegg provides a view of the electrical nature of matter that forms a vital link between the work of Mendeleev on valency and G N Lewis's ideas in chemical bonding*

Chapter 5: Charles Bury, and his detailed electronic structures. *Before discussing the contribution of Bury, this chapter provides an accessible historical review of the development of ideas of electronic structure (And the work of Perrin, Nagaoka, Mayer, Thompson, Rutherford, Bohr, Kossell, Lewis, and Langmuir – some of whom I have heard of!) The work of Bury is seen as a particularly important link between Bohr, Langmuir and Lewis. (The 'potential status' of Bury is exemplified by the fact that the chemist Samuel Glasstone refers to 'The Bohr-Bury' atom – one of the few to recognize Bury's contribution. (p99))*

Chapter 6: John Main Smith the chemist who anticipated Stoner. *He seems to have been a particularly neglected contributor to the theory of electronic structures of atoms. His ideas did not always turn out to be 'right', but he helped to progress/connect the ideas of Bohr and others. Personally, I now admire his judgment since he advocated the placing of hydrogen at the top of any of the main groups of the Periodic Table – with some preference for Groups I* ***and*** *VII because of its univalency!*

Chapter 7: Edmund Stoner, pioneer of the 3rd quantum number. *Stoner provided a more rational basis for electronic structures of atoms and improved the link between these and Bohr's 'Aufbau' principle for the elements in the Periodic Table. His work also proved to be an inspiration for Pauli and the Exclusion Principle.*

Chapter 8: Charles Janet, inventor of the left-step periodic table. *Janet was a savant who contributed to a huge variety of scientific and social fields. Impressively he came late to chemistry at age 78 and devised the left-step pattern for the Periodic Table. I personally have major problems with this since it places helium at the head of Group II and hydrogen unambiguously tops Group I. (The chapter would label me as a 'traditionalist'.) The final section of the chapter explores the meaning of the term 'element' as used by Janet – an important issue for teachers and students of chemistry – as to whether they are 'simple substances' or 'basic substances'.*

Chapter 9: Drawing Things Together. *Overall the author argues for a much messier, more organic development of science than is usually presented. There are many twists and turns and mistakes as science develops. Moreover it is an intensely human process and thus contains a multitude of emotions – jealousy, avarice, nationalism, (joy?) etc. although it is argued, that the resulting science organism (Sci-Gaia?) is unaffected in the long run, by error, inconsistency, issues of priority and human foibles. This chapter aims and largely succeeds in putting the authors 'new' philosophy of science in the context of a large number of other philosophers of science including Kuhn; Popper; Lakatos; Merton; Toulmin; Campbell; Lamb and Easton. It would be impossible – and inappropriate – to attempt here to survey the multitude of interactions, similarities and differences to be found in this chapter, suffice to say that it is a challenging read for those of us who have not studied the history of science and philosophers of science in a similar depth as the author. It is, however, a powerful learning experience giving a perspective on some key issues relating to the development of science. Some of these are listed below:*

- *Scientific Revolutions – or not.*
- *Priority Disputes among scientists*
- *Simultaneous or Multiple Discovery*
- *Inconsistency and error in Scientific Theories*
- *Evolutionary Theories of Scientific Development*
- *Truth or fitness.*

The book is also furnished with a section of Notes and an Index.

As I hope I have indicated in some of the comments above, this is an interesting read for anyone wishing to explore the ways in which science might operate and coming to their own provisional conclusions as to the ways in which science progresses. I guess it could be too much of a challenge for anyone not already reasonably versed in chemistry – especially the electronic structure of atoms and the build-up of (the) Periodic Table(s). It is a text that should find itself available in all chemistry departments in higher education – and is sure to promote discussion, argument and alternative perspectives. There may also be some skepticism and suggestion that time and effort would better be engaged in getting on with ***doing*** science! There are a few (typographical) errors and the occasional internal inconsistency, but these do not affect the overall integrity of the book – and indeed are interesting to find since in some ways their existence helps to validate the evolutionary thesis for progress!

The seven scientists, whose work is covered in chapters 2 – 8, although not famous or not appropriately recognized, were deeply engaged in their worlds of science albeit sometimes providing ideas for others, getting things 'wrong' or even getting them right for the wrong reasons. This leads me to wonder: who are the members of this scientific community? What are the conditions for membership of this community? Can it include people who published nothing, or science technicians, or science teachers. Is a PhD a mandatory requirement? Perhaps even people antagonistic towards science are members, if their engagement happened to catalyse progress by others?

Additionally, the proposed relationship between 'organism' science and that of the community of scientists is still not fully clear to me. There are various statements in the book – e.g. p10: "The view of science that I support is an organic one in which scientific knowledge is viewed as on interconnected organism, a living Gaia like creature……." p22: "what really matters is that science, in the form of the scientific community, makes progress as a whole." p212: "I claim that the society of scientists constitute a unified and living organism." Perhaps they are seen as the same thing? If so, is it possible that a community can be identical to the scientific knowledge it has attained, especially if there are disagreements within the community?

I cannot claim the expertise or philosophical background to critique the thesis in depth/detail. There is much to ponder upon and to wonder about. However, I am still not fully convinced that this new philosophy of science is yet sufficiently defined (in my mind) to oust many of the ideas from philosophy that I have gleaned over the years – and from certain perspectives – have found illuminating. For instance the idea of 'scientific revolutions' seems much less accepted for science although personally I feel that, as a science learner, revolutions seem to occur when new links form between concepts and/or when I realise that current understandings are wrong. Perhaps Kuhn should be classed also as a philosopher of Education?

Having read the text a number of times I still find it interesting from multiple perspectives. New questions arise – will be discussed – and I shall read the book again.

- Eric Scerri is a lecturer in chemistry and in the history and philosophy of science at the University of California, Los Angeles. He has written and published more than 100 research articles, numerous book chapters, is featured in many online video & audio lectures, is the editor of the academic journal, *Foundations of Chemistry*, and has edited or written six books. His 2007 book, *The Story of the Periodic System: Its Development and Its Significance* earned him UCLA's Herbert Newby McCoy award, which honors significant contributions to the science of chemistry. A Tale of Seven Scientists and a New Philosophy of Science is Dr Scerri's seventh book. Visit Dr Scerri's website - http://ericscerri.com/ .

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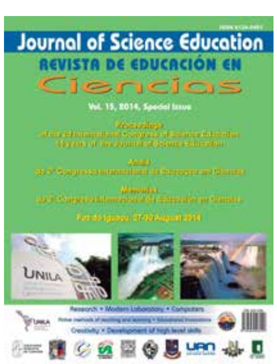

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