motivational beliefs and classroom contextual factors in the process of conceptual change, *Review of Educational Research, 63,* 167-199, 1993.

PINTRICH, P.R., Motivational beliefs as resources for and constraints on conceptual change, en W. SCHNOTZ, S. VOSNIADOU & M. CARRETERO (eds.), *New perspectives on conceptual change* (pp. 33-50), Pergamon, Oxford, 1999.

PINTRICH, P.R., The role of goal orientation in self-regulated learning, en M. BOEKAERTS, P. PINTRICH & M. ZEIDNER (eds.), *Handbook of self-regulation* (pp. 452-494), Academic Press, New York 2000.

POZO, J.I., *Aprender y enseñar ciencia,* Morata, Madrid, 1998.

POZO, J.I., GÓMEZ, M. & SANZ, A., When change does not mean replacement: Different representations for different context, en W. SCHNOTZ, S. VOSNIADOU & M. CARRETERO (eds.), *New perspectives on conceptual change* (pp. 161-174), Pergamon, Oxford, 1999.

PRIETO, T. & BLANCO, A., Visión escolar de la naturaleza y estructura de la materia. *Alambique. Didáctica de las Ciencias Experimentales, 26,* 75-82, 2000.

ROCES, C., TOURÓN, J. & GONZÁLEZ, M., Validación preliminar del CEAM II, *Psicológica, 16,* 347-366, 1995.

ROCES, C., *Estrategias de aprendizaje y motivación en la universidad,* (tesis doctoral no publicada), Universidad de Navarra, Pamplona, 1995.

ROCES, C., GONZÁLEZ-PIENDA, J.A., NÚÑEZ, C., GONZÁLEZ-PUMARIEGA, S., GARCÍA, M. & ÁLVAREZ, L., Relaciones entre motivación, estrategias de aprendizaje y rendimiento académico en estudiantes universitarios, *Revista Electrónica del Departamento de Psicología, Universidad de Valladolid, I, 1,* 41-50, 1999.

SCHNOTZ, W., VOSNIADOU, S. & CARRETERO, M., *New perspectives on conceptual change.* Pergamon, Ámsterdam, 1999.

VILLARROEL, J., Relación entre motivaciones y cambio conceptual en el aprendizaje de las propiedades físicas de la materia en alumnos de secundaria, *Revista de Psicodidáctica, 10,* 17-26, 2000.

VOSNIADOU, S. & BREWER W.F., Mental models of the earth, *Cognitive Psychology, 24,* 535-585, 1992.

VOSNIADOU, S., Capturing and modeling the process of conceptual change, *Learning and Instruction, 4 (1),* 45-69, 1994.

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A decision–support information system for the teaching and the evaluation of environmental aspects to students

Un sistema informático de apoyo para tomar decisiones en la instrucción y evaluación de temas medioambientales

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Abstract

In this paper we present a Web-Based educational programme for studies in Environmental Education. The goal of this application is to help students gain sufficient knowledge about their environment and to realize their role in it as active citizens. The application adapts to the learner's previous knowledge and evaluates the knowledge of the student in particular areas in the study of their environment. Students can work with this programme from remote areas, selecting the subject they want to deal with. Teachers are able to adjust the examination according to their students' performance following a diagnostic test. The advantage of this is the continuous assessment of the student by changing the questions he/she receives from the programme each time according to his/her mistakes in the previous exam. The application has been successfully tested in lower secondary-school students and the results presented are quite encouraging. The application can be installed on a Web-Server and be available in schools, organizations etc, enhancing the availability of e-learning resources.

Key words: *decision–support information system, environmental issues, cross thematic approach, web-based software*

Resumen

Este trabajo presenta un programa educativo en la Web para estudios de educación medioambiental. La meta de esta aplicación es ayudar a los estudiantes en la adquisición del suficiente conocimiento sobre su ambiente y comprender su papel en él como ciudadanos activos. La aplicación se adapta al conocimiento anterior del aprendiz y evalúa el conocimiento del estudiante en particular en las áreas de estudio medioambiental. Los estudiantes pueden trabajar con este programa, seleccionando el asunto de su interés. Los maestros pueden ajustar el examen según la actuación de sus estudiantes con una prueba diagnóstica. La ventaja de esto es la valoración continua del estudiante cuando el sistema cambia las preguntas de acuerdo con los errores del estudiante en el examen anterior. La aplicación se ha probado con éxito en estudiantes de escuela secundaria y los resultados presentados realmente son positivos. La aplicación puede instalarse en un servidor Web y estar disponible para las escuelas, organizaciones, etc., reforzando los recursos virtuales de la enseñanza.

Palabras clave*: sistema informático con apoyo de decisiones, problemas medioambientales, enfoque interdisciplinario, software virtual.*

INTRODUCTION

Over the last couple of decades, there has been an increasing interest in the field of Environmental Studies. This is certainly due to growing environmental problems such as the Greenhouse Effect, Atmospheric Pollution, Extinction of endangered species and over consumption of natural resources and energy in combination with environmental awareness. As a result, new environmental departments have been established in many Universities. Schools also have gradually introduced a variety of environmental courses , Ministries of Education and the Environment and Physical Planning have put forward initiatives towards the careful guidance of the citizens for the protection and better understanding of the environment.

Studies related to Physics of the Environment constitute an excellent candidate to benefit from computer science and especially from the advances of web-based educational software technology. Instructors may use web-based educational software not only to facilitate and complement their process of course delivery and examination, but also to help them evaluate learners. Students can use it to learn, practice, consolidate newly acquired knowledge and examine their knowledge both in and out of the class. Moreover, web-based educational software is accessible to students, adults and full-time employees in remote locations.

The multidisciplinary nature of studies in the Physics of Environment imposes the need for an appropriate web-based educational software whose main characteristic should be the adaptivity to the particular needs of an individual student. Students have diverse backgrounds, different ability of assimilation and therefore different personalities. Furthermore, in case of a web-based educational application, a human teacher is not always needed. All of these create the need for educational software that takes into account the needs and weaknesses of each learner and is adapted accordingly. This application provides knowledge for a variety of environmental topics, examines learners about their environmental knowledge, evaluates learners, indicates errors and weaknesses of learners and suggests topics needing special attention. It covers issues in different areas of environmental studies, and, in particular: House, Garden, Neighborhood, Transportation, Workplace, Marketplace, Excursions, Water, Electricity, Rubbish, Atmospheric Pollution, and Ecology-Recycling

Education is being affected by the changes in the field of new technologies of Information and Communication (ICT). ICT can contribute to the learning process enhancing aspects of teaching such as critical and creative thinking. The cross- thematic approach (CTA), as a way of organizing curricula, attempts to approach school knowledge from a holistic point of view. We can see through the development of the application, the link between ICT with CTA along with the connection of ICT with teaching methods like: Constructivism, Discovery Learning, Problem-Based Learning, Cooperative Learning. Issues connected to Physics, Geography, Mathematics etc are involved in Educational Environment studies in a cross-Thematic approach. Nickerson proposes five principles for fostering understanding when teaching with computers based on research on learning: (NICKERSON 1995)

1) Start where the student is; 2) promote active processing and discovering; 3) use appropriate representations and models; 4) use simulations; and 5) provide a supportive environment.

These principles must always be kept in mind when software is developed, and every effort has been made to implement these in this work. Creating supportive environments has at least three different aspects: organizational, curricular, and teacher training and support.

2. WEB-BASED EDUCATIONAL SOFTWARE

Over the last few decades, the number of people using the Internet for communication, searching information, advertising, e-commerce and education has grown immensely. In addition, there has been an increasing interest for distance education and e-learning due to the fact that these ways of education respect both the learner's time and space. Therefore, there is an increasing demand for Web-Based educational software. Benefits of Web-Based educational software are, among others, the easy access to knowledge whenever and wherever learners want to be educated. Web-Based educational applications are independent of platform. Furthermore, educational systems delivered via the WWW, allow people of all ages to acquire knowledge without attending any school.

Web-based educational applications rely heavily on hypermedia systems. Hypermedia systems include text, pictures, video, sounds, animations and links. Links connect related topics. By clicking on a link, the user is redirected to a subject related to the link. However, the problem with the hypermedia systems and links is navigation. Users can get lost in a site or in a hypertext using links and they may not know where they are and where they were (Dix et al 1993). Web-based educational applications are useful when a human teacher is far away. Therefore, they have to be developed in such a way so as to incorporate the role of the teacher. More specifically, they have to confront to the needs of each learner.

A great deal of existing web-based educational applications is not characterized by high adaptivity and interaction with learners. Recently, a new category of adaptive web-based educational applications, which relies mainly on adaptive hypermedia, has been developed. These educational hypermedia serve the needs of individual learners. Another student modeling technique is the ITS (Intelligent Tutoring systems)-educational applications which involve artificial intelligence techniques (VIRVOU 2002). It is remarkable that the tools required for the development of web-based educational applications, are not especially complex and many of them are available for free on the Internet. These tools are: HTML (Hyper Text Markup Language), Macromedia Flash, Java Applets, Active-X programs and Dynamic Web pages (Active Server Pages - PHP Pages). To execute applications, which have developed with these tools, no special programme or environment is required apart from a browser such as Internet Explorer or Netscape.

3. TOOLS USED THROUGH THE APPLICATION

The tools, which used for the development of the web-based educational applications, are:

HTML: Hyper Text Markup Language is the language for designing web pages. It allows to design web pages which include texts, pictures, images, sounds, elements of forms, videos etc. For the interpretation of the code that is written in HTML browsers, like Internet Explorer and Netscape, are required.

PHP: (PHP: Hypertext Preprocessor or Personal Home Pages) is a widely used general-purpose scripting language that is especially suited for Web development and can be embedded into HTML. It creates dynamic web pages, reading, writing data to databases or files and exacting data from them.

APACHE: It is a web server program that aims to the distribution of the web pages in web sites. The dynamic pages should be designed in PHP in order to be executed into an Apache web server.

MYSQL: It is a relational database server management system. It is used for storing and retrieving data. The MySQL database server embodies an ingenious software architecture that maximises speed and customisability. It cooperates with PHP dynamic web pages. Today MySQL is one of the most popular open source database server management system in the world with more than 4 million installations powering websites, datawarehouses, business applications, logging systems and more.

We have to note that these tools are available on the Internet.

4. WEB-BASED EDUCATIONAL APPLICATION FOR STUDIES IN PHYSICS OF ENVIRONMENT

The web-based educational application for studies in Environmental Education, aims at educating students on the protection of the environment. The application can be divided into three parts: the process of learning, the process of examination and the process of student's evaluation. We have designed this web-based application taking into account four factors:

- The application should be attractive and pedagogical.
- The application should be simple and easy in its usage (simple and friendly interface).
- The fact that students have different backgrounds, level of knowledge, ability of assimilation and personalities.
- The fact that the teacher is not usually present (we are faced with the concept of the e-tutor).

The last two factors suggest that the application should support both student and teacher modeling. For this reason, during the examination process, the application checks the learner's answers and stores the errors in the database. Then, the database data are used as the input for the process of teaching and the application adapts the teaching process according to the learner's needs and weaknesses.

For student modeling, the application must be able to recognize the learner who uses the program each time. For this reason, each learner has a username and a password. To obtain a username and a password, a learner has to follow the registration process that is provided by the application. During the registration process, the application checks the username and the password, which are selected by the learner, so that it is ensured that each user of the educational application has a unique username and password.

Due to the fact that the process of learning should be easy in use and friendly to learners, the tutoring subjects have been divided into categories, which are related to areas within which citizens usually move and act. These categories are the following:

- House
- Garden and Balcony
- Neighborhood
- Transportation
- Workplace
- Marketplace
- Excursions

These categories are links guiding the student to find information and practices related to the corresponding category. The information, which is related to the above categories, is divided into subcategories in favor of structured knowledge. These subcategories are the following:

- Water
- Electricity
- Rubbish
- Atmospheric Pollution
- Ecology-Recycling

When a learner is visiting the Website of the educational application for the first time, he/she will have to follow the process of registration and recognition in order to move to the process of learning. In this case the application does not know the knowledge level of the learner, thus neither advice nor suggestions are given to him/her during the learning process. On the other hand, if a learner has already used the application, the application takes into account the learner's answers to previous exams and adapts the learning process to the learner's needs and weaknesses. More specifically, the application checks and counts the wrong answers which the learner gave to an exam in previous executions, and provides a guide for the learning process, displaying a picture next to each main category.

This picture represents the learner's knowledge level for the corresponding category. The pictures, which characterize the level knowledge of a learner, are the following:

- : the learner's level knowledge is excellent (right answers: 90-100/100).
- : the learner's level knowledge is good (right answers: 75-90/100).
- : the learner's level knowledge is moderate (right answers: 50-75/100).
- : the learner's level knowledge is bad (right answers: 0-50/100).

Figure 1. Categories of the tutorial

Moreover, into the text to which each main category-link leads, a picture displayed next to the points that are related to subcategories in which the learner should give more attention. Due to available links, the student can move freely and easily from one category to another during the learning process.

After the learning process, the examination process begins. During this process, the student can examine his/her environmental knowledge through answering questions. Our educational application provides two kinds of exams: a static exam that includes thirty questions and is available to all users and a dynamic exam which is adapted each time to the learner's weaknesses and includes different questions according to the wrong answers which he/she gave to exams in a previous execution of the application. The questions of the dynamic text are retrieved from the database. Needless to say, the dynamic exam is only available to learners who have used the application at least once. Both tests include questions where each has two or three possible answers (multiple-choice) from which only one is absolutely right. A degree (0, 5 or 10) corresponds to each answer, which indicates how wrong the answer is. For example, if a student selects an answer with degree 0, that means that the given answer is completely wrong. Moreover, the application allows teachers to change the questions of dynamic test, inserting new questions in the database, deleting or modifying old ones. We use this way to design the exams because multiple-choice technique allows the easy checking of learner's wrong and right answers.

The goal of our educational application is the gradual improvement of students' knowledge level about environmental issues. The examination process is not enough for the achievement of this goal; learner's evaluation is also needed. For the learner's evaluation, the type of the mistakes should be identified according to the grades described earlier, and finally to classify the mistakes according to the different categories of the Environmental disciplines. We have categorized exam questions, each question corresponding to one of the main categories and to one of the subcategories that are presented in the learning process. The percentages of learners' errors per category are stored in the application's database. Thus, our application has an accurate knowledge about the level and the progress of students.

At the end of the examination, the learner may see the results. These include a message, which indicates the learner's knowledge level, and some links that lead to the subjects in which the learner has weaknesses. The added value of the application is the information provided to the student, teacher, central policy makers and parents on the progress of the students.

This is implemented by displaying four tables:

- A table where the percentages of errors per category are presented (House, Garden and Balcony, Neighborhood, Transportation, Workplace, Marketplace, Excursions) made by the learner during the latest examination and the percentages of errors of the same categories made by the learner during the previous examination.
- A table where the percentages of errors per subcategory are presented (Water, Electricity, Rubbishes, Atmosphere pollution, Ecology-Recycling) which are made by the learner during the latest examination and the percentages of errors of the same categories which are made by the learner during the previous examination.
- A table where the percentages of total errors per category are presented (House, Garden and Balcony, Neighborhood, Transfer, Job, Marketplace, Excursions), which are made by the learner during all the examinations.
- A table where the percentages of total errors per category are presented (Water, Electricity, Rubbishes, Atmosphere pollution, Ecology-Recycling), which are made by the learner during all the examinations.

Figure 2. Comments after the test

Figure 3. Results of each category

The general educational process, which is provided by our application, is depicted in the Figure 1 where our system's activities are presented and in the Figure 2, which presents the interactions between the learner and our educational application in chronological order. For the design of these figures, UML (Unified Modeling Language) was used.

5. PROPOSED ACTIVITIES

During the process,students were also involved in activities concerning their envirionment.The activities included:

a. Domestic refuse. Students could be involved in the following activities.

Composting: waste organic matter can be placed in compost bins and recycled. This produces a rich fertilizer and soil aerator for the garden

The diagram below illustrates the process of recycling waste organic matter using a simple compost bin. This incorporates learning by action. (FORD & MAYS 1997).

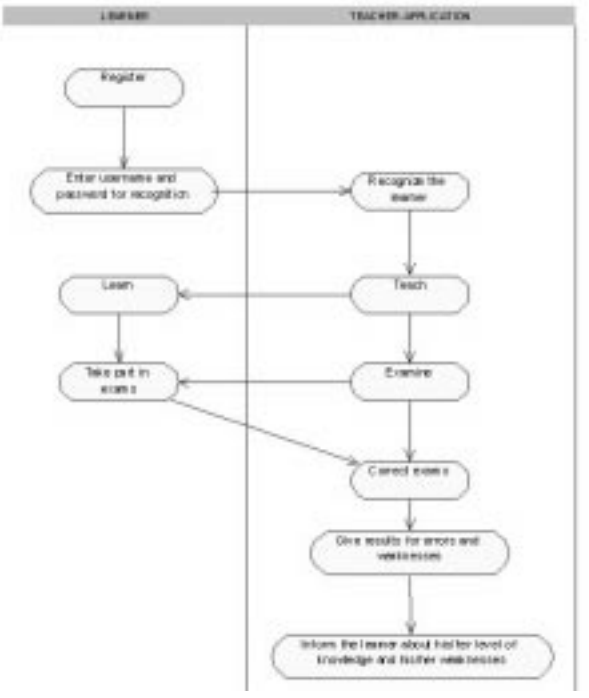

Figure 4. UML Activity Diagram

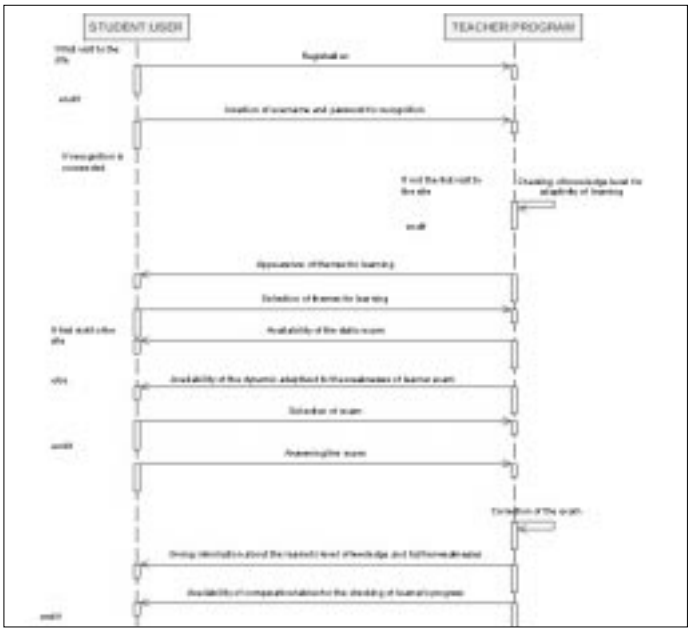

Figure 5. UML Collaboration Diagram

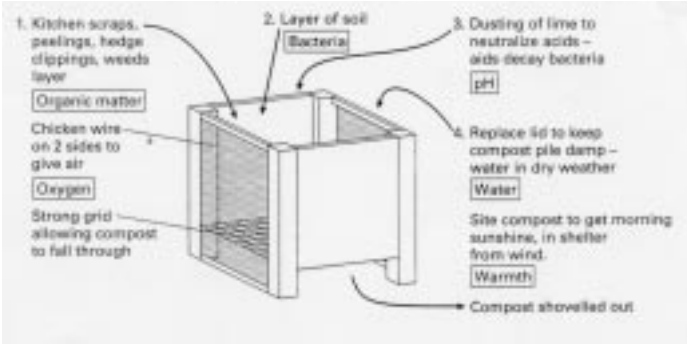

Figure 6: A simple compost maker

b. Recycling: Materials such as paper, glass, metals, can be recycled when binned separately. Students may collect such waste materials from their homes, separate them according to the categories mentioned above and contact the local recycling companies to collect them. The same process could be repeated on the site of a beach, mountain, and forest if the student has access to it.
c. For students living near their schools, recreational parks etc., they may adopt the bicycle as a means of transport, emphasizing environmental awareness.
d. School students could test the acidity of the soil in their playground, by measuring the PH at different locations. This will make them aware of the effects of acid rain on the local ecosystem.
e. Following activity d, students could then produce a map showing the vegetation type and cover. This could be achieved with the use of a quadrat (a loop wire thrown randomly on the soil). Students will become aware of the vegetation, which is constantly under threat from acid rain. We emphasize the interdisciplinary approach, since most of the above activities contain aspects from Mathematics (Statistics), Chemistry (PH), Biology (organic matter), Geography (maps), etc.

6. RESULTS AND DISCUSSION

Using freeware tools, we constructed software to help the student learn about different areas of Environmental studies. The paper illustrates this with a working example of an "expert-pedagogic" database for storing pertinent details of selected questions on different aspects of Educational Environment studies. Hence, during the period of reflection, the application enters the realm of 'paradigm shift' in that it examines the students past rationale, her/his actions and the consequent results within new knowledge received. This procedure enhances the learning by a reception learning process where new meanings are obtained by asking questions and getting clarification of relationships between old and new concepts and propositions. The acquisition of knowledge is achieved by "hands-on" activities from the students during the exploration of the application. The development is currently being researched and tested at the Irakleitos Science Center (www.irakleitos.gr) and the first results are quite encouraging.

Two groups of students used the software in order to check the effectiveness. The first group consisted of 16 students (aged 13 years old) from Private School 'Nea Paideia'. The second group consisted of 37 students (aged 16 years old) from Science Center 'Irakleitos'. Both groups took the test and the results are divided in phase 1, which is before the tutorial, phase 2 that takes place after the students have studied the online tutorial and phase 3 that takes place after another study of the online tutorial. The software calculates the error percentage in each category and it produces table with the grades. The grades of them have been collected and the mean has been calculated for each phase in each category, correct to one decimal place.

From the above tables it is obvious that the error percentage is decreasing accordingly to the study of the online tutorial. The remarkable fact is that students have a great comprehension of the issues taught even after the first study of the online tutorial.

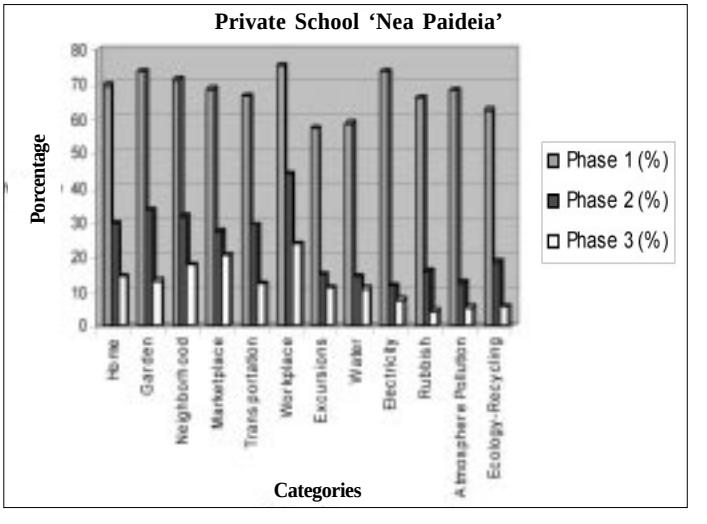

Figure 7 : Results of students from Private School 'Nea Paideia' - the % is the % of errors

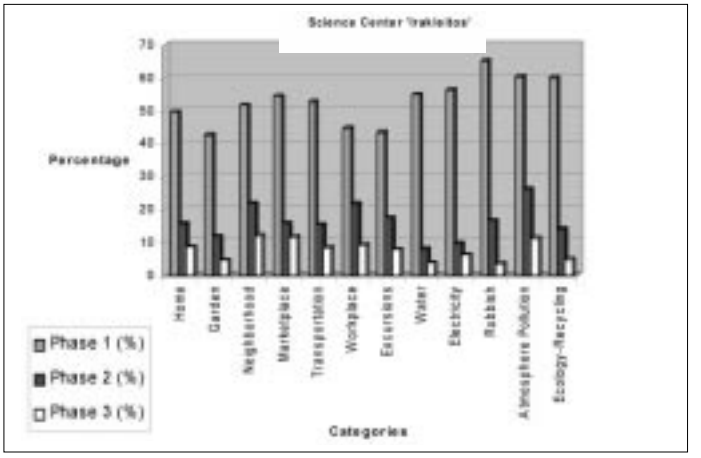

Figure 8: Results of students from Science Center 'Irakleitos'- the % is the % of errors

7. CONCLUSIONS

The application can be used for the creation of projects connecting different disciplines (Mathematics, Physics, Geography, etc.) involved in the Education of environmental issues. The whole work also supports the recent ideas on situated learning (BROWN, COLLINS & DUGUID 1989). Their work has inspired researchers to consider the significance of the environment as a motivating factor for learning.

Our results are also in accordance to the research based on the sociocultural tradition (LAVE and WENGER 1991), (ROGOFF 1990) They had criticised the fact that knowledge and skills learned in school are not directly, as such, applicable to situations outside school, in which case the commitment to learn is left inadequate and factitious. Instead they propose learning should take place in authentic and complex social contexts.

BIBLIOGRAPHY

BROWN, J.S.; COLLINS, A; DUGUID, P., "Situated cognition and the culture of learning", *Educational Researcher*, 18(1), 32-42, 1989.

DIX, A.; FINLAY, J.; ABOWD, G. & BEALE, R., *Human-Computer Interaction*. Prentice-Hall, 1993.

FORD-ROBERTSON, J., MAYS, T., *Letts GCSE Biology*, Letts Educational, Great Britain, 1997, pp. 193.

Table 1
Results of students from Private School 'Nea Paideia', the % is the % of errors

Category	Phase 1 (%)	Phase 2 (%)	Phase 3 (%)
Home	69,6	29,8	14,5
Garden	73,8	33,8	13,2
Neighborhood	71,4	31,6	17,9
Marketplace	68,7	27,6	20,4
Transportation	66,6	29,7	12,5
Workplace	75,3	44,0	23,8
Excursions	57,3	15,2	11,2
Water	58,5	14,3	10,9
Electricity	73,9	11,8	7,6
Rubbish	66,1	15,9	4,4
Atmospheric Pollution	68,5	12,7	5,3
Ecology-Recycling	62,7	18,8	5,6

Table 2
Results of students from Science Center 'Irakleitos', the % is the % of errors

Category	Phase 1 (%)	Phase 2 (%)	Phase 3 (%)
Home	49,6	15,7	8,7
Garden	42,7	11,8	4,7
Neighborhood	51,7	21,9	12,2
Marketplace	54,4	15,9	11,6
Transportation	52,6	15,5	8,5
Workplace	44,7	21,8	9,2
Excursions	43,5	17,6	7,9
Water	54,8	8,1	3,8
Electricity	56,4	9,7	6,3
Rubbish	65,2	16,8	3,6
Atmospheric Pollution	60,4	26,4	11,2
Ecology-Recycling	59,9	14,2	4,9

LAVE, J., WENGER, E., *Situated Learning: Legitimate peripheral participation*, Cambridge University Press, New York, 1991.

NICKERSON, R.S., "Can technology help teach for understanding?" in *Software goes to school*, ed. D.N. PERKINS, J.L. SCHWARTZ, M.M. WEST, & M.S. WISKE, Oxford University Press, New York, 1995.

ROGOFF, B., *Apprenticeship in thinking*, Oxford University Press, New York 1990.

VIRVOU, M., "Educational Software Technology for environmental studies", Proceedings of the International Conference "Protection and Restoration of the Environment VI", Skiathos, July 1-5, 2002, pp. 1553-1560.

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La enseñanza de la óptica geométrica: algunas estrategias didácticas
Teaching geometric optics: didactic strategies

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Resumen

En este trabajo se evalúan dos modelos de instrucción, uno basado en las premisas constructivistas y otro basado en un modelo expositivo-deductivo. El tema elegido ha sido la óptica geométrica en el nivel de segundo de bachillerato español. Son datos recopilados a lo largo de tres cursos académicos 1998/1999, 1999/2000 y, 2000/2001. La investigación fue llevada a cabo con la misma profesora de secundaria tanto en el grupo de control como en el experimental. El resultado muestra qué estrategias constructivistas en la enseñanza tienen una influencia positiva sobre el aprendizaje de conceptos científicos.

***Palabras clave**: constructivismo, ideas alternativas, ideas previas, investigación didáctica, óptica geométrica.*

Abstract

In this study, we evaluate two models of instruction, one based on the assumptions of the constructivist model and the other based on an expositive-deductive model. We applied the two approaches to the teaching of Geometric Optics, in level A, during three academic courses. In each case, the same teacher taught the same scientific topic to both the control and the experimental groups. The results show that constructivist strategies in teaching have a positive influence on the learning of scientific concepts.

***Key words**: Alternative ideas, constructivism, didactic research, Geometric Optics, previous ideas.*

INTRODUCCIÓN

El objetivo general de esta investigación consiste en indagar en las concepciones de los alumnos respecto de los contenidos fundamentales de óptica geométrica y, en concreto, en aquellas que no son modificadas o lo hacen de un modo parcial tras los períodos de enseñanza formal, a fin de establecer estrategias didácticas que favorezcan este cambio hacia las concepciones más acordes con la ortodoxia científica. Se inscribe dentro del marco teórico del *modelo constructivista* o *movimiento de las concepciones alternativas*. Dicho modelo representa la tendencia más aceptada en la producción investigadora actual y pone su énfasis en el conocimiento previo de los alumnos antes de las situaciones de enseñanza formal para, a través de unas metodologías instructivas adecuadas y consecuentes, poder aproximarlo al conocimiento científicamente aceptado.

Hasta el momento se han abordado numerosos estudios tendentes a la descripción sistemática de las concepciones de los estudiantes con relación a las distintas disciplinas científicas pero, especialmente, en el campo de la física. Aunque en el tópico de óptica geométrica no son abundantes los