Web-based Exploratory Cross-curricular Learning Contexts

The Case Studies of IRIS and GAIA Environments

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Abstract The pedagogic implementation of web-based exploratory learning contexts through the examples of the IRIS and GAIA educational software is discussed. IRIS and GAIA are two learning environments based on multiple representations addressing the teaching of subjects such as physics, mathematics, geography and visual arts through a cross-curricular and project oriented approach. The pedagogic and methodological principles that guide the design of these environments is being outlined followed by examples of the ways in which experimentation and construction can facilitate the learning in different subjects.

1. INTRODUCTION

The implementation and use of interactive technology tools introduces new habits and roles in the didactic practice (Chronaki 2000). Students and teachers come to relate in different ways not only with the tools but also amongst themselves. Specifically, such tools promote users' direct manipulation of information and their active engagement with the content represented in the software. As a result, the pedagogic context of such a tool is rooted in the design principles, but also in the way of its implementation

by teachers and students in the classroom. The focus of this paper is to highlight some pedagogic implementation of web based exploratory learning contexts through the examples of the IRIS and GAIA educational software.

2. DESIGNING EXPLORATORY LEARNING ENVIRONMENTS

The design of IRIS and GAIA exploratory software is based on pedagogic principles rooted in the theories of constructivism and socioculturalism (Papert 1991, Resnick 1995). These pedagogic principles have emerged through a methodology involving a dialogue between theory and teaching practice. This dialogue was materialised in two levels. First, the design team was interdisciplinary, involving people with different expertise and experiences (i.e. subject teachers, educationists and software designers). Second, there was a close co-operation between the team members and classroom teachers. This meant that any original idea concerning design could be discussed from both theoretical and practical viewpoints but also such ideas could be tested in real conditions that would enable to get feedback from teachers and students. The pedagogic principles can be summarised in the following five basic guidelines for the design and implementation of the educational software.

Approaching concept learning through problem-solving in authentic situations The basic idea in both environments of IRIS and GAIA is that the didactic treatment of concepts in specific subjects should emerge through the solving of problems arising in authentic situations. Such situations are closely connected with situations we are faced in real life (e.g. the construction of a town square in IRIS, the trip around the Earth in GAIA) and which mostly have a cross-curricular character. Through such open contexts, subject specific questions can be posed. For example, questions such as: "what is vector and how can be measured?", "how we measure the sides of a triangle?", "what is area and how can be measured?", "what might be a good form for decorating the floor of the square?" address the subjects of physics, maths and visual arts.

Use of experimentation and constructions Whilst working with specific tasks in the IRIS and GAIA environments, teachers and students can experiment with either real situations (i.e. in the case of IRIS) or simulations of real situations (i.e. in the case of GAIA). Experimentation allows the users to approach a problem from a variety of viewpoints and moreover encourage them to try out their own envisaged solutions (e.g. simulate trips on the surface and on the atmosphere, in GAIA, construct linear, free forms and create mosaics and decorative motives, in IRIS). Experimentation and

construction takes place in a specially designed web space, called the 'activities centre'.

Systematic use of information and communication In both environments users are encouraged to utilise systematically information. Especially, two centres have been designed to encourage users towards searching, discussing and reflecting about information. These web-based centres are called the 'information centre' and the 'communication centre'. The 'information centre' consists an interactive database that includes information in the form of multimedia. This information is relevant to the suggested tasks and aims to assist learners in their work through projects and worksheets. The 'communication centre' enables learners and teachers to actively interact and discuss online aspects concerning their involvement with the tasks.

Promotion of collaborative learning and teaching The learning environments of IRIS and GAIA require students and teachers to collaborate at many different levels. First, students should collaborate whilst working in small groups of two or three in their worksheets. Second, teachers and students collaborate in the classroom whilst experimenting and reflecting on their work through specific tasks. Finally, online distance collaboration amongst students and teachers who work on same topics (through specifically designed tasks) but in other schools is also encouraged. For example, the measurement of the Earth's radius necessitates the collaboration between two schools, as well as the exploration of ultimate forms in constructing and designing the town square encourages interaction amongst students and teachers who live in very different locations.

Promotion of critical, political and aesthetic thinking The topics and especially the questions found in the proposed tasks aim to promote students' critical, political and aesthetic thinking over situations. For example, questions about decision making concerning issues of design, construction and the economy of a particular space such as the town square are closely related with people's political and critical thought in a community where they share activity and life. Choosing one solution over another means that these people have treated aspects of the problem not only rationally, but also critically, politically and aesthetically.

3. ELABORATING EXPERIMENTATION AND CONSTRUCTION

Viewing the development of learning as an active endeavour of students necessitates that the pedagogic design of a didactic situation encourages participants in 'doing' and 'trying out' their ideas. Both GAIA and IRIS offer specially designed tools that can be used for *experimentation* and

construction in particular tasks. Such tools promote specific activities (i.e. through visualisation, simulation, direct manipulation and multiple representations) that enable users' exploration and work in experiments and constructions.

Multiple representations (Van Someren et al. 1998), in particular, are based on the idea that exploratory learning can be achieved when students move from one representation to another in a way that is meaningful for the purpose of their activities. The use of multiple representations is strongly exploited when the parameters of interactivity, that modify the working area, act as multiple inputs. In other words, one can move the explorer around the globe and/or the world map by clicking and dragging on it and/or changing the value of longitude and latitude.

3.1 Examples from GAIA

GAIA is realised through seven microworlds, covering a different thematic areas related to Earth (the Greek word GAIA is a synonym of the word Earth). Each microworld is equipped with a number of tools, interaction items and representations that are integrated with the correct educational material in order to support different educational scenarios (Kotsanis et al. 2000).

One of the most well specified scenarios is the one that helps students understand the concepts of geographical longitude and latitude, in the *Jason microworld*. The users have at their disposal an 'explorer', for example a plane or a helicopter, that is shown and can be visually manipulated (Lemeignan et al. 1996) in the following four representations (see Figure 1).

Planet Earth shows a three-dimensional sphere with earth's image that the students can rotate eastwards or westwards. Choosing a point on the sphere's surface allows the user to designate the explorer's position, which corresponds to a longitude and a latitude value-pair that are represented, in turn, by a meridian and a parallel respectively. *World Map* shows the explorer's position on the earth's map. Using direct manipulation the students can change its location. *Sections* consists of two hemispheres. The South hemisphere is used to show the longitude on the surface that corresponds to the equator, via an indicator that moves in a circle scaled from 180 to 180 degrees. A vertical hemisphere is used to show the latitude on the surface that corresponds to a meridian, via an indicator that moves in a semicircle scaled from 90 to 90 degrees. The explorer's attributes, such as location, velocity and distance can be manipulated through the *Flight Deck*. *Flight Deck* consists of many controls and instruments representing a variety of attributes related to the microworld.

Figure 1. Sections, Planet Earth, World Map and Flight Deck representations

Students can change the explorer's location in four different ways: (1) with direct manipulation of the explorer, either on Planet Earth, or on the World Map; (2) with rotation of the wheel, or change the position on the Flight Deck; (3) with the change of the arithmetic value (in degrees) of longitude and/or latitude, either on Planet Earth, or the Flight Deck; and (4) with direct manipulation of the three-dimensional representations of longitude and latitude in Sections. Any of the above changes triggers a simultaneous update of all the representations depicting the explorer's location.

In addition to Jason, GAIA supports six other microworlds (Newton, Gilbert, Eratosthenes, Torricelli, Egkelados and Aristarchos) that enable students to:

- Observe satellite orbits around any planet of the solar system, and solve problems related to the velocity and type of orbit;
- Study earth's geomagnetic field, the characteristics of the magnetic needle and the effects of mineral deposits on magnetometers;
- Calculate earth's radius, following the procedure used by the Greek mathematician Eratosthenes before 2300 years;
- Measure the pressure and temperature of the earth's atmosphere, to study levity and to simulate free fall;
- 'Travel' inside esoteric part (crust, mantle, core) and study it through a simplified model of seismographers; and
- Study the orbits of the planets in a model of earth's solar system or even in an imaginary solar system that users can construct by choosing planets with different characteristics.

It should be noted that an explorer is used in all microworlds. However, depending on the microworld, the explorer that is represented by a different object and therefore image. For example, in Jason microworld students can choose between an airplane, a helicopter or a ship, in Gilbert a magnetic

needle or a magnetometer, and in Torricelli a balloon, an airplane, or a parachutist.

3.2 Examples from IRIS

The constructions and experiments in the local environment of IRIS, occur through three tools (see Figure 2): two *Unit Constructors* for vectors and bitmaps and a *Motif Generator* (Kotsanis et al. 1999). Along with the two *Unit Constructors*, the user creates either vector designs or graphics and images in bitmap format. Both constructors provide the basic geometric shapes (point, segment, open polygon line, closed polygon line, square, rectangle, circle, arc, regular polygon) with the possibility of either colouring the line and filling the shape, as well as a set of mathematical transformations such as symmetry, rotations, displacement, stretch and resizing. The function that differentiates the two constructors, beyond the format of the design is the selection of a grid. In the first (which resembles the simplified Geometric Sketchpad) (Rowling 1997), the grid is made up of dots on which the shapes can be constructed. In the second (which resembles Windows Paint), the grid is made up of a rectangular area, which can be filled with colour.

The *Motif Generator* repeats the simple or complex units made by the unit constructors as motifs, in a rectangular area, with horizontal and vertical sizes that can be modified. One to four units can be placed (only one or two horizontally or two vertically or four adjoin units) in each of which we can use the function: flip horizontal/vertical and rotation, to construct a motif.

The above development of these tools is not based on the approach of multiple representations and direct manipulation. The user exploits the tools independently either through file management or by just taking advantage of copy/paste functions. In the new (under development) version of Iris, the approach of multiple inputs through four representations is being used. The first three include the functions for the construction of a *unit*, a *motif* (which is made up of one to four units), and a *mosaic*, which repeats the current motif. Through the fourth representation, the *sketch deck*, the user can interact directly to each and every one of the parameters of the other representations. The result appears directly in one of the other representations and concurrently have the result projected in the other two. For example, the user can: change the current colour or shape of the unit to a series of other colours and shapes, modify one of the units using the flip horizontal/vertical and rotation functions, and change the number/size of repeated motifs (see Figure 3).

Figure 2. The Unit Constructors and Motif Generator tools

Figure 3. Unit, Motif, Mosaic and Sketch Deck representations

4. CONSTRUCTIVE USE OF WEB TOOLS

An important element of the design considerations for both educational software case studies, is the provision of web-based facilities which allow the building of a 'network learning community' around these educational applications and their school use for connected classrooms.

Hence, both GAIA and IRIS are designed such as to provide access to a web-based Learning Community Centre (LCC). This is not a static information retrieval focal point on the web, but it serves as the enabling platform for the community members to organise their activities. Therefore, the Learning Community Centre is constantly being constructed by its users. We consider this as an integral part of the educational software itself, and

moreover, as an important element of the internet-based constructionist aspect of the connected classroom use of the software.

Constructionism (Papert 1991) involves claims that learning is an active process, in which people actively construct knowledge from their experiences in the world. Recently, the term 'distributed constructivism' (Resnick 1995) is introduced, to describe how the basic constructionist thesis can be enhanced by an emphasis on the social dimension of such activities when shared among many participants.

This is the rational based on which the concept of Network Learning Community Centre is developed. The main objective of the web-based LCC is not to create a fully self-sufficient information web site for users to enjoy, but to provide the basic framework and facilities towards building communities of learners engaged in collaborative activities that involve not only the exchange of information but also collective construction of personally meaningful activities and knowledge accumulation. As a result, both educational software case studies presented in this paper are supported on-line with a web-based Network Learning Community Centre consisting of the following three centres (Sampson 1999).

Figure 4. List of Images from the Information Centre

The *Information* centre provides user-friendly access to databases of educational material and content (in various forms, such as, text, images, graphs, video and web-links, e.g. Figure 4). Although, a seed material is pre-stored in these databases, all registered users (learning community members) are given the privileges to upload new material from emerging collaborative project activities.

The *Communication* centre provides the necessary tools to enable communication via Internet, facilitating the exchange of ideas and collaboration between on-line community members.

The *Activities* centre provides the workplace and the tools for the on-line activities experimentation. Exploiting the facilities of both the Information centre (for example work sheets or relevant stored activity material) and the Communication centre (for example discussions between community members) the community members can construct their own project activities. The Activities centre gives them, also, the opportunity to experience, criticise and eventually learn from the constructions of others. This enhances the potential of the exploratory educational software in use from an environment of personal expression to a learning environment through which the individual learner encounters and interprets a symbolic representation embodying the ideas of others.

5. CONCLUSIONS

Tasks in the proposed exploratory environments address topics that cover the curriculum in several secondary subjects such as science, geography, maths and visual arts. They provide tools for the teaching of these curriculum subjects through tasks and activities that promote open and exploratory learning. This pedagogic context is based on the use of simulations, experimentation and constructions as well as the communicative and collaborative interactions achieved amongst participants either face to face or online. Current piloting of the implementation of these learning environments in classroom conditions provides very optimistic results and feedback on the success of such contexts as far as it concerns the learning development and conceptual change for both teachers and learners.

Note: The first phase of GAIA and IRIS was developed on the frame of the SIRINES and NAUSICA projects, while the second phase of GAIA is currently being developed on the frame of the PENELOPE (EPEAEK projects funded by the Hellenic Ministry of Education, Greece, under the co-ordination of the Computer Technology Institute – CTI).

REFERENCES

- Chronaki, A. (2000) Computers in Classrooms: learners and teachers in new roles. In *International Companion in Education*, B. Moon, S. Brown, and M. Ben-Peretz (eds.), Routledge, London.

- Kotsanis Y., Chronaki, A., Taliadorou L. et al. (1999) *Technical Annex*, IRIS: The Art of Mathematics and the Mathematics of Art, EPEAEK/NAYSIKA Project. [<http://www.compupress.gr/iris>].
- Kotsanis Y., Dapontes N., Karastathis V., Sampson D. et al (2000) *Technical Annex*, GAIA II: Educational Multimedia Microworlds for Cross-Curriculum Earth Navigation, EPEAEK/PINELOPI Project. [<http://gaia.compulink.gr>].
- Lemeignan G. and Weil-Barais (1996) *Construire Des Concepts En Physique. L'Enseignement de la Mecanique*, Paris.
- Papert, Seymour (1991) Situating Constructionism. In *Constructionism*, Idit Harel and Seymour Papert (Eds.), Norwood, NJ: Ablex Publishing, 1991.
- Resnick M. (1995) New Paradigms for Computing, New Paradigms for Thinking, Computers and Exploratory Learning. In A. diSessa, C. Hoyles and R. Noss (eds.), *Computers and Exploratory Learning*, Springer Verlag NATO ASI Series, pp. 31-44.
- Rowling, Dawn (1997) *Introducing The Geometer's Sketchpad to the Classroom*. The Global Schoolhouse.
- Sampson D. (1999) Collaborative Learning in School Education via the World Wide Web: The NETLogo Project. *European Multimedia, Embedded Systems and Electronic Commerce Conference*, EMMSEC'99, June 1999, Stockholm, Sweden, pp. 21-23.
- Van Someren, M., Reimann, P., Boshuizen, P. and De Jong, T. (1998) *Learning with Multiple Representations*, Pergamon.

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