A GEOGRAPHYCAL INFORMATION SYSTEM IN A VIRTUAL LEARNING ENVIRONMENT

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ABSTRACT

The use of Information and Communication Technologies (ICT) in education has widened the range of learning possibilities and provides the required technological support to create a new learning environment.

This paper focuses on the description of an improved educational environment based on a system of data visualization and a geographical information system. It describes a proposal for integrating theory and practice in the learning process, improving visualization and customization of learning methods.

Afterwards, an approach based on a Geographical Information System (GIS) is presented which is adapted to the requirements of a virtual learning environment.

KEY WORDS

Innovative Web-based Teaching and Learning Technologies, E-learning, Web Based Education, Virtual Labs, Data Visualization, Geographical Information System.

1. Introduction

Information and Communication Technologies (ICT) are inducing significant social and cultural changes that are producing a shock in learning environments, as has been proved in several publications and research studies in this last decade. [1] [2] [3]
This research work takes place in Computing, Multimedia and Telecommunication Studies (EIMT) at the Open University of Catalonia (UOC), whose main feature is to develop an asynchronous, on-line and 100% virtual learning system. Learning is achieved within a virtual campus environment.
The multidisciplinary research group which is called the Information and Communication Systems and Services (ICSS) carries out its activities in such a context. At the moment, it is working on the use of ICT applied to learning environments focusing on covering learning necessities at the UOC. In order to achieve this, it pays special attention to the role of Higher Education in a network environment, tackling aspects like curricular design, professional competences and information management mechanisms.
Members of the ICSS represent a wide range of knowledge areas: ICT, pedagogy and visual design. That is a key aspect as it allows us to solve the main issue in all the involved areas, such as the multimedia principles applied to education, security access to the system, database management, visual design, and so on.
This paper presents a proposal for using a Geographical Information System (GIS) in a virtual learning environment. This work is divided in four sections: Firstly, we will analyse the current virtual environment at the UOC as well as the aspects that we wish to improve. Secondly, we will analyze the reason for using a visualisation system and a GIS for e-Learning. Next, the GIS and its potential in a pedagogical environment will be described and a particular hypothetical application will be shown together with examples developed. Last of all, our conclusions and future lines of work will be described.

2. Analysis of the current virtual environment

The UOC, like other European Universities, is now involved in a process of adaptation to the European Higher Education Space (EHES) that involves a new approach to the educational system.

In this new scenario, the student is the centre of the teaching and learning process, and he/she has to take a proactive and autonomous role. As a result, the syllabus will not be designed with respect learning to objectives but to competences that have to be acquired by students based on their curricula profiles. An advantage of that is that from the very beginning, the UOC has located the student at the core of its learning model, as shown in Figure 1.

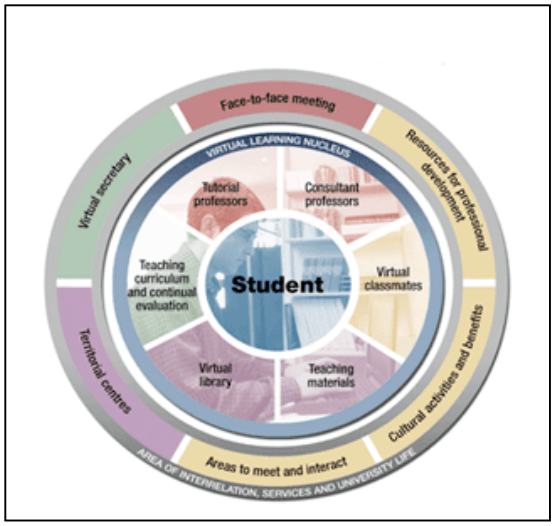

Fig.1: UOC Pedagogical model with student in the middle

At the UOC, learning and teaching processes take place in an asynchronous and on-line environment, as mentioned before. The scenario where this process takes place is a virtual campus, a proprietary tool specifically developed for the UOC. The basic cell for students is the classroom, which is associated to one subject. There, they have a place to share knowledge, communicate with both the teacher and other students, and also to get some resources (see Figure 2).

First of all, we would like to underline the specificity of EIMT studies. At first sight it may seem such a difficult degree to develop in a virtual environment due to its high practical and technical nature, since practical learning acquires a greater relevance. The goal is to relate theoretical concepts to the practical part of it.

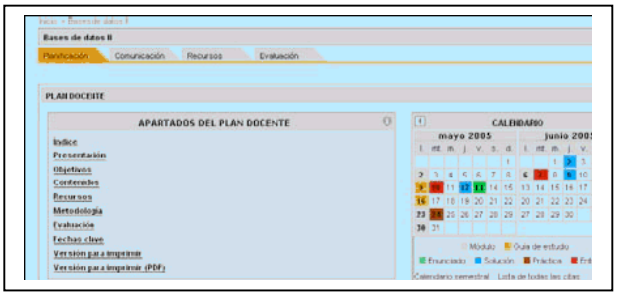

Fig.2: UOC virtual classroom

According to EHES' guidelines, our point of view in the learning perspective must change. One of the important issues of this new learning model is education by means of competences (knowledge, abilities and skills) that compels to have a strong relationship between practice and theory. These changes suggest, for instance, a complete monitoring (follow-up) of student activities in the virtual classroom. This undoubtedly means that it will be essential to develop technical solutions that allow access to this kind of information for a proper follow-up and management of the student learning process.

Traditionally, instructional design models based on objects have been applied in virtual learning to manage the differentiation between theoretical and practical objectives. This differentiation is remarked in face-to-face learning environments as there is an actual separation between the classroom and the laboratory. Inheriting from traditional learning models, this separation -classroom and laboratory and consequently theory and practice– takes place also in the virtual learning environment. It is easy to overcome this barrier though, as there are no physical barriers in a virtual classroom: theoretical contents are taught in the classroom and they are applied in the laboratories where practical exercises are carried out following a similar model to a face to face learning model. In other words, current Learning Management Systems (LMS) are simulating face-to-face structure.

Moreover, current virtual learning environments do not use all the potential of visualization and interaction that the Internet may offer nowadays. Instead, they should allow:

- Designing degree maps thereby providing access at any moment to the necessary data for student placement
- Avoiding common feelings of confusion in a virtual learning environment
- Allowing access to some information, as sometimes that could be a problem in a traditional Learning Management System
- Providing students to identify their own learning pathway. In the same way, subjects could benefit from these improvements in terms of visualization and adaptation to the learning itinerary

In other words, it is possible to represent relationships between contents graphically, between these ones and the evaluation elements, between theory and practice as well as providing students with tools that allow them to embody their itinerary and their navigation route visually according to their previous interests and knowledge; in order words, turning the graphic interface into a study guideline or syllabus.

On the other hand, it is also convenient for monitoring of all student activities (consulting contents, results of evaluation tests, contributions to the classroom, and the like) and having at our disposal a system that provides us access to these kinds of data, as it is important to carry out a continuous evaluation of the students' work.

Definitely, we think that e-learning platforms need to evolve according to new methods of teaching and learning that require a learning environment which is able to overcome all the previously mentioned facts.

3. Why a visualization system for e-learning?

In a technological Degree that is taught in an online university based on a Learning System Management Environment, we need to work with a huge quantity of data and students, lecturers and administrative employees have to deal with different sorts of information that are often inter-related. At the same time, the virtual environment should be able to communicate easily and pleasantly since people spend many hours working in it. In other words, we need effective information communication for an e-learning environment.

Before making a proposal to find a solution to these issues, we would like to make a general reflection about our context, our needs and our thoughts.

On the one hand, the network is step by step becoming more and more visual. There are lots of web sites that are mainly visual, and not only with only text information, but information access also enters the everyday life of users and becomes increasingly ubiquitous and pervasive. Users need to make sense of the web in the least possible time.

On the other hand, internet users are nowadays used to dealing with applications like Google maps that make navigation through the network different from what it used to be and it provides a new way of interactivity and at the same time shows a more complex reality. Another way of familiarization with geographical tools is the GPS with its specific software. So, we can find lots of locative systems to manage information although this used to be geographical information or information related to places.

But first, we have to describe what we have called a visualization system. It is a set of tools to integrate Information Design and Data Visualization; technologies and methods that allow people to communicate technical and specific information in an effective way and at the same time to extract at a glance the most meaning from this information. So, we can say that information design focuses on an effective information communication from a rational and scientific point of view. Data visualization is clue to find immediate meanings to a huge amount of information. According to Matt Woolman "functional visualizations are more than innovative statistical analyses and computational algorithms. They must make sense to the user and require a visual language system that uses colour, shape, line, hierarchy and composition to communicate clearly and appropriately, much like the alphabetic and character-based languages used worldwide between humans." [4]

It is proved that dynamic and interactive data visualization could manage that people notice complex but essential data about whatever we need to know or to show, and it could be done in an amazing and revelatory way. The success of websites like *Information aesthetic* [5], word formed by Lev Manovich [6], *Dataesthetics* [7] or *Visualcomplexity* [8] prove the interest in this area. We are not going to go deeply in this area because we are not interested in data visualization in an aesthetic sense but in the communication of complex knowledge and the management of a large quantity of information.

So, if we apply these theories to e-learning, we really think, and this is one of our hypotheses, that the use of tools for data visualization is highly recommended in e-learning because we can teach revealing its complexity. These kinds of tools have a great didactic value and their use could help lecturers to teach contents showing all the complexity and how they are related to other contents. At the same time, their use could help students in several senses that we will analyse later. Furthermore, we have to take into account that data presentation can be beautiful and nice as well as descriptive. Andrew Vande Moere says "following Louis Henry Sullivan's design concept of 'form follows function', one can thus imagine a similar concept of 'form follows data'" [9]. There is a variety of conventional ways to visualize data, but we are not going to analyze them now.

Secondly, we think that the Internet and communication tool users are used to dealing with geographical information systems. Each passing day, we are more and more used to managing geographic tools. If we want to find a restaurant, we would address a geographical information system with concrete information: Google maps, Google earth, and several mashups that have emerged involving the Google initiative and last but not least, GPS. The introduction of all these tools has produced what is called "locative thinking". The success of videogames based on cities and places has also helped this kind of thinking and knowledge. All these systems assume a sort of navigation and interaction that can be used in an effective e-learning environment, although it has the potential of data visualization. Another positive point is that data could be administered in an intuitive way.

With a Geographical Information System, which could be outsourced via web, we can link contents that apparently are disconnected or it is difficult to see the connection. As indicated, it is possible to draw up learning itineraries or routes to facilitate the access to information and navigation.

Hence, visualization has the potential to go beyond the conventional goals of finding data patterns, making better-informed decisions or communicating knowledge and a Geographical Information System adds the potential of locative thinking with conceptual maps and the management of huge amounts of information.

Concluding, we believe that techniques for data visualization:

- Allow people to assimilate and manage information as fast as possible
- Deepen understanding of knowledge by visually illustrating data in effective ways and a greater comprehension of complexity and show hidden relations among data
- Presenting information in a comfortable environment makes comprehension easier
- Design complex structures

And a Geographical Information System:

- Allows to manage a huge database in a visual way
- Facilitates locative thinking and linking objects
- Achieves drawing paths
- Provides a navigation path closer to student habits

Hence, we make the proposal that is shown in next section.

4. Proposal

Several Learning Management Systems (LMS) – such as Moodle, WebCT, Fronter, Sakai and Blackboard – have been analyzed by the research group, and all of them are based on information architectures, information representation and navigation design typical from the early days of the network: they are closer to a list of information than in a visual way.

Furthermore, all the literature that has been consulted and analyzed regarding this subject does not deal with integration of online labs in virtual learning environments, although it is a very good theoretical base from a pedagogical point of view [10]. Neither has it dealt with the role of labs in the curricula design of the new degrees according to the Bologna process and the EHES.

After this analysis, we decided to do some research on the creation of our own model based on adapting a system that was not at first created for e-learning: a Geographical Information System (GIS). We are going to integrate this information system into a specific Learning Management System. We think that this kind of system will allow a response to the demands of visualization, integration and monitoring.

This section is structured in three parts: first of all, we analyze what a GIS is and how we can adapt this technology to our necessities; then we introduce an example of this adaptation by means of a pedagogical GIS; and in the last subsection, we will show the value of using a GIS.

4.1. Geographical Information System

In this subsection, we will analyze what a GIS is and how it is possible to avoid the "Geo" of the geographic. Then, we will show why we have chosen a GIS.

4.1.1. Avoiding the "Geo" of Geographical

A GIS is a kind of very special application that combines different elements from different areas, like that of physics, mathematics, computing, cartography and topography, among others. In fact, we can find many and very assorted definitions [11]. One of them could be: "A computing database that contains spatial information" [12]. In the broadest sense, we could say that a GIS is composed of hardware, software, data, users and business rules.

But maybe one of the widest definitions of a GIS is: "A GIS is a mix of hardware, personal and geographical data designed for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to Earth. In a more generic sense, a GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present graphically the results of all these operations" [13].

From the definitions, it is clear that one of the key points of a GIS is that of geographical data, which we can find even in the very origin of GIS. But we are interested in the "more generic sense of its definition": "a GIS is a tool that allows users to create interactive queries (user created searches), analyzing spatial information, editing data, maps, and presenting the results of all these operations". "Geographical data" is data referred to the Earth, but why not refer data to another reference system, a conceptual reference system for instance? Then, we can use a GIS as a way to represent abstract information. And we can go one step further and use a GIS as a way to represent information and use all of its powerful tools.

In fact, this is not a new idea: conceptual maps have been used in many different subjects from the very beginning: pedagogy [14], history [15], etc. What is actually new, though, is using a GIS as a tool for representing this kind of maps. On the other hand, we must not forget that, besides the graphical part of a GIS, it is also important the database and tools behind it that allow users to exploit information.

Once that "old" concept of a GIS has been changed, we can make a "map" where, instead of states we see subjects, instead of countries we see parts of a subject, instead of infrastructures we see resources, etc. Furthermore, the size of subjects could be their related number of credits instead of square meters; and the distance between subjects could be a "conceptual distance" instead of km: for instance, History will be further away from Physics than Mathematics.

4.1.2. The reason of a GIS

Our next important question is: does it make any sense to use a conceptual map as a navigation tool? Using a GIS, we have all the power of this kind of tool; but conceptually, using a map we are using the experience of mankind in the drawing up and utilization of maps.

Probably, a map is one of the most natural ways of representing information: mankind has been using visual representation before written communication and has been using maps for several thousands of years. Computers have been using lists of written information not because of their usability, but because it was simpler with the available technology at that moment. Operative systems based on windows (like MacOS®, Windows ® or Ubuntu) produced more usability, but in some cases they are only a better way of representing lists of information, and the more popular LMS is an example of this.

Web 2.0 has meant a first step for change: people can now find a lot of web pages where information allows interaction in a visual environment instead of a list. On the other hand, people have become used to webpages like Google Maps or GPS navigators where maps play the main role, as we have said before. People have also become used to interaction and maps in computers and technology. Success in all of these resources shows how these ways of representing information, closer to the way mankind has always been using, is easier for people to handle, use and understand. Furthermore, all of these resources also show that technology has evolved to make it possible to use these ways of representing information in the computer; and a GIS could be the paradigm where all of these resources converge.

The next section presents an example of this fact by showing a GIS as a pedagogical tool.

4.2. Example of a pedagogical GIS

The first step to construct a GIS is to design the "spatial" database. It is not like the databases we are used to designing because there is a graphical component involved here. Then, it is important to decide the fields of the table, and the kind of geometry that this table will have. For example, in a geographical GIS it can be decided that the cities will be points, counties will be areas and rivers will be lines.

In this first approach to the pedagogical GIS the following components with the following kind of geometry have been used:

Component	Description	Geometry
Subject	Subject	Area
Chapter	Part of a subject	Area
Resource	Element in a chapter that links to the item that contains the information: text, a simulation, a commentary from the teacher, etc.	Point
Competence	A competence to be acquired	Line
Road	The link between two elements that shows the route to be followed	Line

The size of the area geometries is related with the weight in credits. Then, a subject with 9 credits is bigger than a subject with only 4. The subjects that can be attended in Telecommunications Engineering at the UOC are represented in figure 3. The size of the circles' area represents the number of credits. Then, in a very visual way, one can see the subjects that should involve more work.

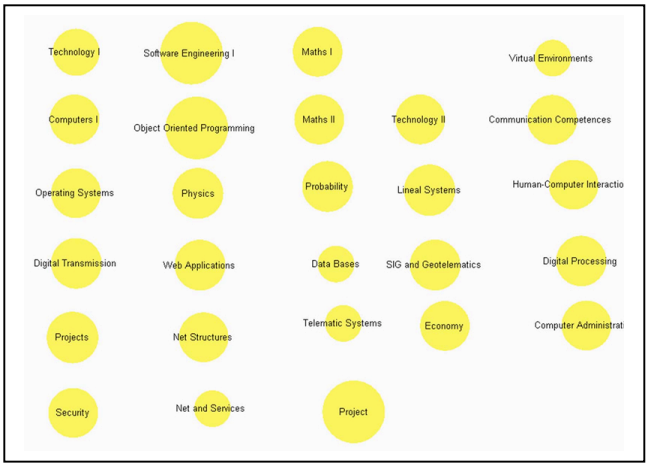

Figure 3: Representation of the subjects of the Telecommunications studies at the UOC

Zooming in (in the same way as we would do in Google Maps or our GPS navigator), for example, the subject of physics, we see the chapters of the subject. They are also represented as circles (Figure 4), and every circle has the area corresponding to its weight of credits.

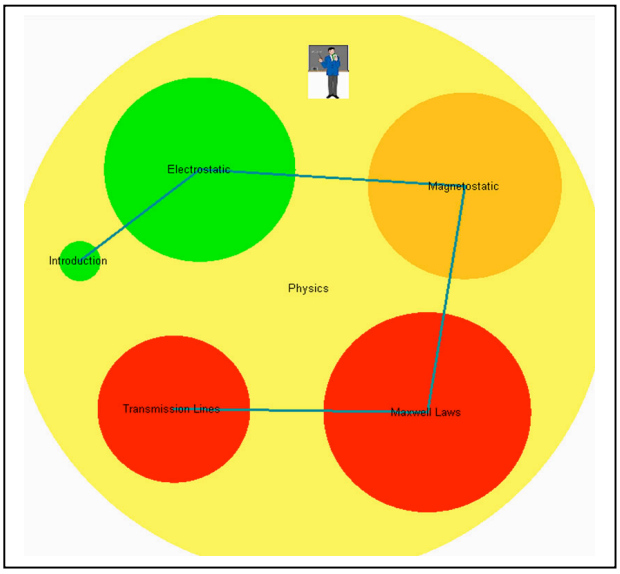

Figure 4: Chapters inside Physics subject

The line in the figure represents the "road" that a student should follow, and shows the order in which he or she should work through the chapters. The meaning of colors will be shown later on in this paper.

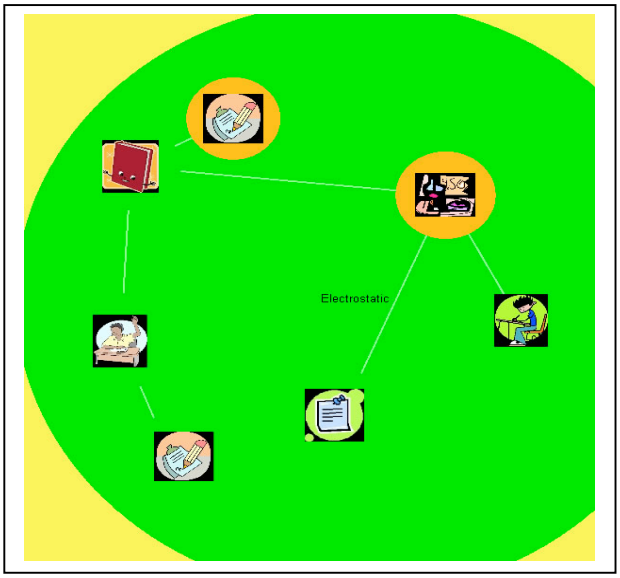

Figure 5: Resources of electrostatics subject

Zooming once again, for example, the chapter of "Electrostatics", the student can see the resources that he or she has in order to acquire the competences corresponding to this activity (Figure 5). The student has access to any kind of resource: text, virtual labs, notes from the teacher, evaluation tests, etc. He/She has also got the route that should be followed. Then, we see that this system allows us to put an end to the traditional distinction between theory, laboratories, and suggestions from the teacher, etc. Everything is integrated in one space where all is inter-related. What is important is what the student has to learn and the best way to learn it, and not if now he or she has got to go to the laboratory or to the classroom.

4.3. The value of a pedagogical gis

In the previous sections, we have seen what the GIS looks like, however, a GIS has also a lot of tools to exploit this information. We will just show some of its infinite number of tools in this section.

4.3.1. Competences

One of the things represented in a GIS are the competences. They are represented as a line. But since there can be a lot of competences, showing all the lines could be useless. It would probably be worthwhile to show the subjects where a competence has to be acquired. In Figure 6, one can see the subjects where the competence "work in group" appears. What is important is that we only need to have the competences in the database in order to get this information with one "click".

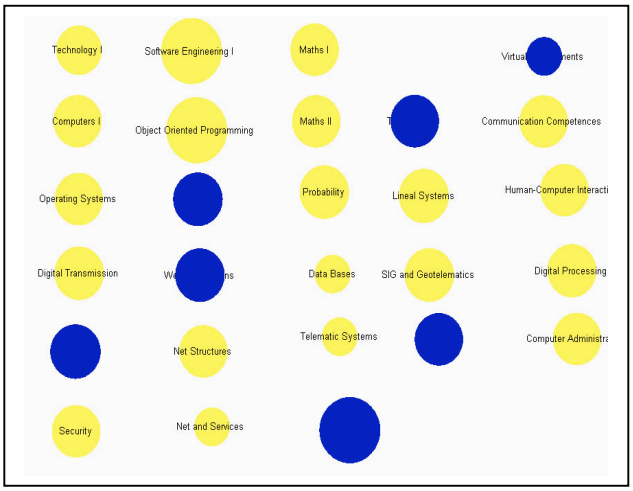

Figure 6: On blue subjects where the competence "Work in group" is found

4.3.2. Subjects related with success index

Another piece of information that can be useful for that are more difficult for students, i.e., represent the subjects with different colours as a function of the rate of students that pass the subject. In Figure 7, the subjects are shown with a different colour that shows the rate of students that pass the subject: green, between 75% and 100%; blue, between 50% and 75%; orange, between 25% and 50%; and red, less than 25%.

This information could be useful for teachers and department heads, to know which subjects are more

problematic, but also for students, because they can know which subjects probably will need some “extra” work.

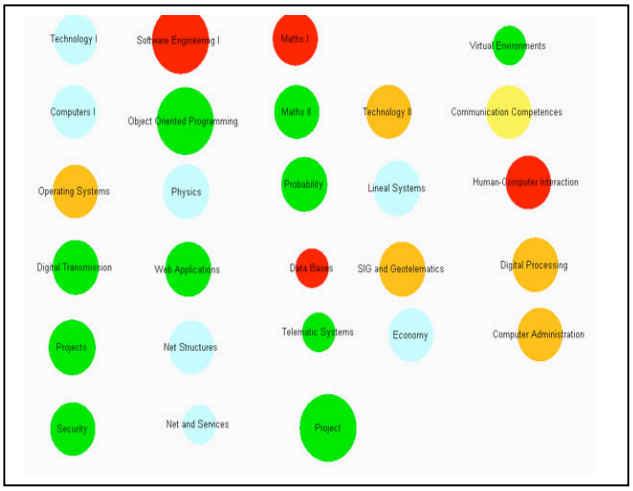

Figure 7: Subjects on function of the number of students that pass it: green, between 75% and 100%; blue, between 50% and 75%; orange, between 25% and 50%; and red, less than 25%.

4.3.3. Progress in a subject

A student can be interested in knowing what he or she should have been doing that week in a subject. In Figure 8, the chapters are shown, and colours mean what part should have already been done (green), which part is in progress (purple), and which part have not yet been worked on (red).

The student can be interested not only in what are the suggestions of the teacher, but also in his/her own progress. The GIS keeps also the information about the progress of the student, and then can show which is the difference between his/her progress and the progress indicated by the teacher.

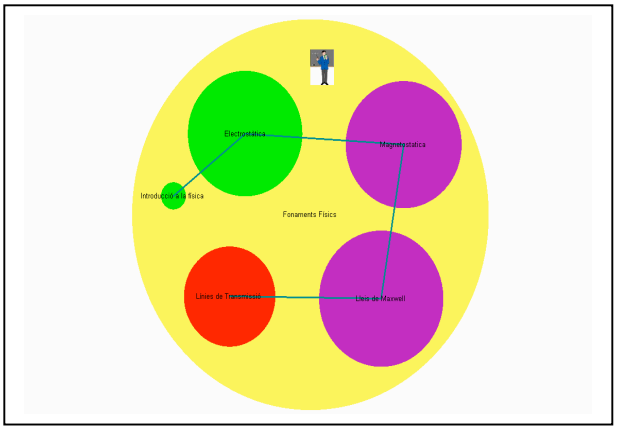

Figure 8: Purple signifies the difference between the progress of a student and that indicated by the teacher

4.3.4. Monitorization

One of the key points of the GIS is the database. It allows all the queries we have seen in the previous items. But it is also important because it can store what the student does and what is his/her progress. In the previous item, we have seen how a student could represent its progress; but the teacher has also access to this information and then could know how the student is progressing. Having access to all this information allows the study of the behaviour of students and teaching can adapt to them.

4.3.5 Self-configuration

Having the information of students in the database also allows one to keep the information of what each one prefers. Not all of us work in the same way or always do the same thing. For example, a student probably wants to see a chapter of Physics each time he or she gets into the GIS when he or she is in the middle of the year; but probably wants to see all the subjects when he or she is preparing their enrollment.

4.3.6 Web outsource

Finally, in studies like those developed at the UOC, where everything is online, the tool is only useful if it can be accessed via web. Therefore, everything that we have shown must be accessed via web.

5. Conclusion

This paper has permitted us to review that current virtual learning environments are not using all the potential of visualization, interaction and monitoring that the Internet allows today.

In our teaching practice, we have stated that a new environment that allows designing degree maps, easier access to information, and clarify learning itineraries could be very useful and effective to improve online learning and teaching.

After analyzing different LMS’s, we are going to design and develop a prototype that mixes data visualization techniques with a geographical information system. It should allow us to assimilate and manage huge quantities of information quite fast, have a deeper understanding of knowledge and comprehension of data complexity together with revealing hidden links among data, and, at the same time, it could provide a comfortable environment closer to the Internet navigation habits.

In this context, we have proposed a GIS as a solution that could give a response to these requirements.

A GIS is a powerful tool that has the advantages of a database and a visualizations system to which everyone is very used to and it also uses a conceptual map to show information.

Another important feature is that a GIS can allow students and teachers to configure their own point of view and everyone can see, from the very beginning, what is more

interesting for him or her. The tool is adapted to the user, and not the user to the tool.

Last but not least, we really think that the use of tools for data visualization is highly recommended in e-learning. And the next steps of our research are:

- To finish a prototype of a Pedagogical GIS
- To implement a web outsource
- Test it with students

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