

Study of Graphical Issues in a Tool for Dynamically Visualising Student Models

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Abstract. This paper describes *DynMap*, a system based on Concept Maps for dynamically visualizing the Learner Model of an Intelligent Tutoring System (ITS). The aim is to facilitate learners and teachers to better understand ITS outcomes. The paper, first, describes some domain issues of IRIS authoring tool. Then, the main characteristics of Concept Map Editor are listed. Next, the functionality and the components of *DynMap* are presented. Finally, the results of the study conducted on the graphical resources of *DynMap* are presented.

Introduction

Intelligent Tutoring Systems (ITSs) define an active and still promising area in computer-aided education. However, it is demonstrable that the really hard and complex task of ITS construction and exploitation has impeded their wide-scale use. Teachers are suspicious when they have to hand over part of their tasks to the ITS. Members of the educational community, specially those who have not enough experience in the computational field, have a lot of problems when working with ITSs. In order to alleviate this problem different research lines have arisen. Regarding ITS construction, a main research line pursues the generation of authoring tools valid to build ITSs in a wide variety of domains [10]. Regarding ITS exploitation some important aspects must be considered: can teachers manipulate/visualize tutor components?, do teachers understand automatic tutor outcomes?, what kind of representation, textual or graphical, is more appropriate for representing them?, It is important that tutor outcomes can be presented to members of the educational community in such a way that they can be easily understood.

In recent years it has become apparent to many educational researchers that representing knowledge in a visual format allows one to better recognize and/or understand incoming information. It is easier for the brain to make meaning when information is presented in visual formats; visual symbols are quickly and easily recognized. Up to now, several authors have considered visualization and inspection of tutor components. Most effort has been oriented to consider visualization and inspection of student models [13]. This approach, known as Open Student Modelling, allows the student to inspect their model thereby facilitating reflection [4]. Cook and Kay [5] make one of the first attempts for representing graphically the learner model; they use a mixture of text and conceptual trees based diagrams. Morales *et al.* [9] present a table-like graphical representation format of the learner model for a sensory-motor task in which every row represents a rule. Bull and Nghiem [3] claims that the use of simple learner models, easy to represent in different ways, e.g. graphical and tabular, allows teachers and students to better understand students' learning of a target domain. VisMod [14] provides a flexible architecture where students and teachers can create their own views of a student model by choosing nodes they want to inspect from the Bayesian network that represents the student model. In addition, Dimitrova *et al.* [6] justify an approach of inspecting and discussing the learner model in a graphical manner using conceptual graphs. They argue that the selection of an appropriate

communication medium reduces comprehension problems, facilitates reasoning about learner's behaviour, and promotes metacognitive processes.

The final goal we pursue in our research is to increase teachers' participation in ITS decisions. It is necessary that teachers understand ITS outcomes to get this aim. In this paper we will show how Concept Mapping is an appropriate technique for visualizing the student model. A *Concept Map* (CM) is a graphical way of representing and organizing knowledge. It is comprised of nodes and links, arranged in some order to reflect the information domain being represented. Nodes represent concepts, and links represent the relationship between concepts; both concepts and links are labelled and may be categorized. Although concept mapping has become an increasingly popular advanced teaching and learning tool, originally it was defined as a method to present knowledge and information in a graphical way [11].

1. IRIS

IRIS [1] is an authoring tool developed to help human instructors to build intelligent teaching-learning systems in a variety of domains. The *Domain* of the tutors built by using IRIS contains the explicit representation of the content to be taught organized from a pedagogical point of view. Four basic elements describe the domain:

- Basic Learning Units (BLUs) or kind of teaching-learning contents. Based on Merrill's Component Display Theory [8] IRIS represents any domain in terms of the following four BLUs –concepts, procedures, principles and facts.
- Pedagogical Relationships between contents. In order to establish a pedagogical view for selecting and/or sequencing the BLUs, IRIS includes two types of relationships, structural relationships –is-a, part-of, and sequential relationships –prerequisite, corequisite, postrequisite and next.
- Instructional Objectives (IOs) or skills to be reached. IOs refer to the application of particular skills over BLUs. They form a useful part both in planning the teaching-learning process and in creating didactic activities. The default IOs in IRIS are those of the widely accepted Bloom's taxonomy [2] – knowledge, comprehension, application, analysis, synthesis and evaluation.
- Didactic resources (DRs). Any kind of IO needs a set of presentation resources or techniques which can be used to present the domain BLUs to the learner – definitions, examples, analogies, etc.– and evaluation resources or techniques for assessing domain contents – tests, fill gaps, item sorting, etc.–.

The *Learner Model*, based on an overlay approach, defines the individual learning characteristics and the knowledge evolution of each student; it is built up during the teaching-learning process.

2. CM-ED Tool

CM-ED (Concept Map EDitor) is a flexible general purpose tool for editing CMs. The aim of the tool, implemented in Java, is to be useful in different contexts and uses of the educational agenda, concretely inside the computer-based teaching and learning area. On the one hand, it is a common concept mapping editor in which the user can draw nodes and relations generating different CMs. Consequently, it can be used as a general purpose cognitive tool for supporting learning. On the other hand, the tool can be adapted to specific purposes (some of them are described below). The specialization of the tool for concretes purposes is implemented by means of *templates*. A template specifies the kind of nodes, relations and restriction operations that are going to be used in a set of CMs. All those elements have an explicit representation in XML. In order to specialise the tool, it is

necessary to perform two steps. Firstly, the user designs an appropriate template. Then, the tool adapts the interface to meet the template specification. This means that the tool is restricted to the resources (types of nodes, relations and restriction operations) specified in the template. And secondly, the final user works with the adapted tool and produces the CM.

The exploitation of CM-ED in computer-based teaching/learning environments for helping the user both in the learning process and in the preparation of the teaching material includes the next three possibilities:

First, CM-ED is useful as a *complementary tool* to support the learning process. Constructing their own CMs helps students to identify important concepts, organize them graphically and identify semantic relations between those concepts. CMs are useful for visual learners who can memorise information contained in a picture.

Second, CM-ED widens the set of *learning activities* [7]. CMs can be the basis to design other kind of exercises different from typical tests and fill-in-gaps. Concretely, IRIS used CM-ED in order to gather from the author the exercises based on CMs.

Finally, CM-ED has been used *to represent the domain knowledge* in IRIS [12]. The subject matter intended to be taught to the learner is represented in a graphical way. In order to alleviate the difficulties found in users while working with IRIS, an interface based on CMs had been developed. The user represents the complete teaching domain by means of a CM. S/he specifies the instances of BLUs and the pedagogical relationships between them together with the DRs to teach each BLU. In order to offer more flexibility to the user when s/he develops the domain, the interface offers three windows corresponding to different views of the CM:

- The *Domain Structure view* (left side of Figure 1) represents the set of BLUs of the domain and the pedagogical relationships.
- The *BLU view* (right side of Figure 1) shows the information related to the BLU selected in the Domain Structure view. This information is shown by a tree that represents the components of the BLU, the IOs and the DRs. The purpose of this window is to allow the user to establish the relations between BLUs and DRs.
- The *DR view* shows the complete set of didactic resources ordered by type.

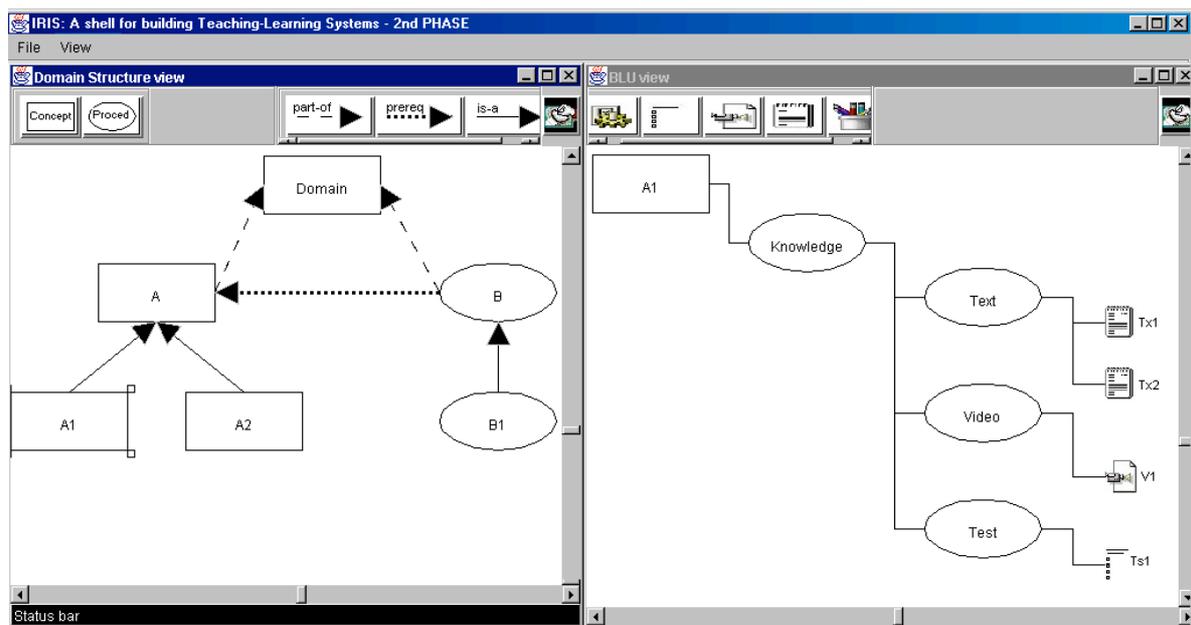


Figure 1. Representing the contents of the domain

The three views share the same structure. In the left upper side of the window there are two button bars: the node bar and the relation types bar. The set of nodes and relations of these bars are different in each view. In the right upper side there is a rubber button. The

bottom of the window corresponds to the working area in which there is a view of the CM. The user manipulates the three view windows in the same way. S/he creates new nodes by dragging and dropping the generic types of the upper side to the working area and deletes them by moving the rubber to the node. The mechanism to set relations between nodes is also simple. First the user selects the relation type and then the nodes that it connects. Relations are also deleted with the rubber.

3. Representing the Student Model with Concept Maps

The main goal of DynMap is to show graphically the *internal student model* of an ITS to both the student and the teacher. DynMap represents the student model intuitively in a concept map way and it includes specialized tools for inspecting the student model addressed to both kind of users. It uses the core of CM-ED adapted by means of a template. The template defines the nodes and relations that appears in the concept map and restricts the operations that the users can perform. The internal student model of an ITS changes through the learning process. Therefore DynMap is able not only to keep the current state of the student knowledge but also to record the evolution of the student through the learning sessions. This feature is used to show dynamically the sequence of states of the student model. Despite the common way of visualising the knowledge of the student, the inspectors are different for the two users as it is explained below.

The domain model represented by means of concept maps (Figure 1) is used as the basis for the graphical view of the student model. Both Domain Structure and BLU views have their correspondence to represent what the student knows. As explained above the knowledge of the student is articulated in BLUs, IOs and DRs. The main concept map, **General View**, shows the complete picture, *i.e.*, the BLUs that the student has studied, so it corresponds with the Domain Structure view. However, the only relationships shown are the structural ones: is-a and part-of. The **BLU view** displays the information of a BLU.

The next graphic resources are used to show different characteristics of the concepts represented by the nodes of a concept map:

- **Form**: type of the node, for example BLU, IO or DR.
- **Size**: degree of knowledge about the BLU/IO/DR. There are four sizes, the bigger the node, the better the knowledge.
- **Thickness**: a thick border represents that the student has worked enough the BLU/IO is, for example when the student has done an appropriate number of exercises or has spent enough time (there are three values).
- **Line**: a dashed border represents that the BLU/IO is not completely achieved, otherwise the line will be continuous.
- **Colour**: is related to the time when the item was worked, *red* for current BLU/IO/DRs and *green* for already achieved BLU/IO/DRs.
- **Flag**: this graphic resource is used to mark that the node (BLU/IO/DR) has attached comments, this notes can be written by either the teacher or the student.

4. Components of DynMap

DynMap is composed of a knowledge base that maintains the set of students concept maps, the *DynMap Repository*, and three functional modules: *Translator*, *Student-DynMap* and *Teacher-DynMap* (Figure 2). The translator is a piece of code to be integrated into the ITS while Student-DynMap and Teacher-DynMap are independent Java applications.

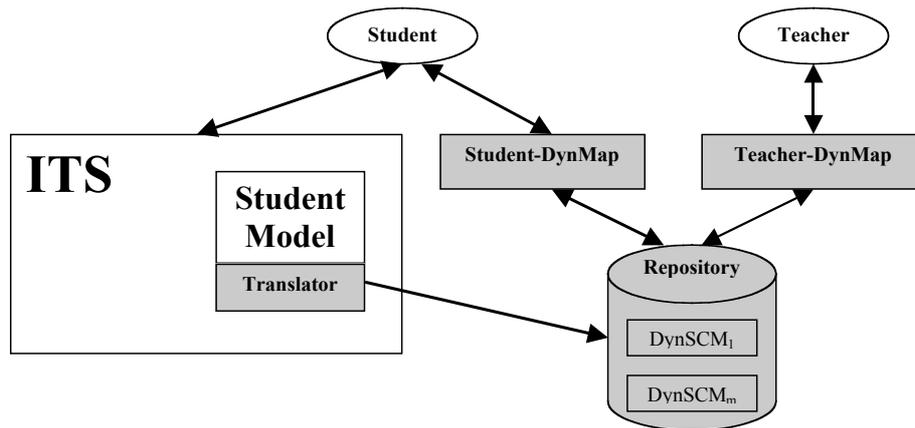


Figure 2. Components of DynMap

4.1 DynMap Repository

This repository manages the storage of the dynamic evolution of all the students' concept maps. Due to performance issues, it is not appropriate to save the whole map after every small change. The chosen solution is to store the complete state of the **Student Concept Map** (SCM) after each learning session and the changes performed on it while the session is carrying out in the **Operations Log** file. An Operation Log contains the sequence of operations performed in a session and the time when each one was done. Therefore, the **Dynamic Student Concept Map** (DynSCM) is composed of a sequence of SCM and Operation Logs: the initial SCM, the Operation Log of the first session, the SCM after the first session and so on. The upper side of Figure 3 shows the evolution of the internal Student Model of the ITS during one session and the bottom side the DynSCM of the student. SCM_i and SCM_{i+1} are the stages before and after the session i and OL_i is the operation log corresponding to the operations performed during that session. Using the storing facilities of CM-ED the DynSCMs are represented in XML.

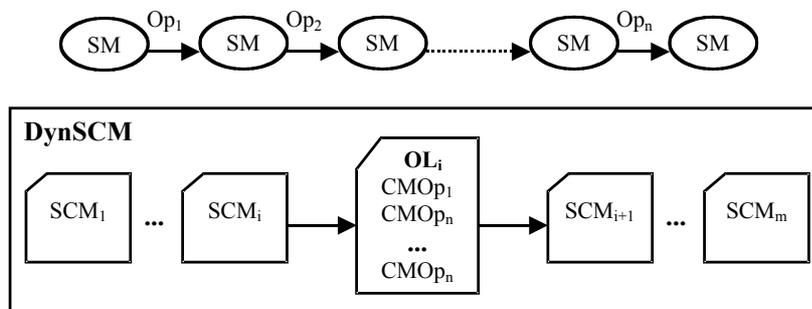


Figure 3. Evolution of the student in one session

4.2 Translator

This module is responsible for connecting the ITS with the inspection tools. Therefore, the translator is a piece of code integrated into the ITS. It translates the internal learner model of the ITS to the concept map representation. Concretely, it translates the changes made to the internal student model to CM-ED operations and stores them in the Operations Log. This is done by overloading the methods that change the original student module in order to add operations that translate these changes to changes in the concept map based student model.

4.3 Teacher-DynMap

Once the identity of the user is checked, this component allows the teacher to select the student to observe by means of a browser. Then, the teacher can observe the DynSCM that represent the beliefs of the system about the current state and the evolution of the student's

knowledge. It shows the Student Concept Map dynamically. Using the set of video-like buttons of the tool bar (Figure 4) the user can move through the learning process of the students. The evolution of the concept map can be observed at two levels of detail: jumping between each basic change in a session or between each session in the learning process.

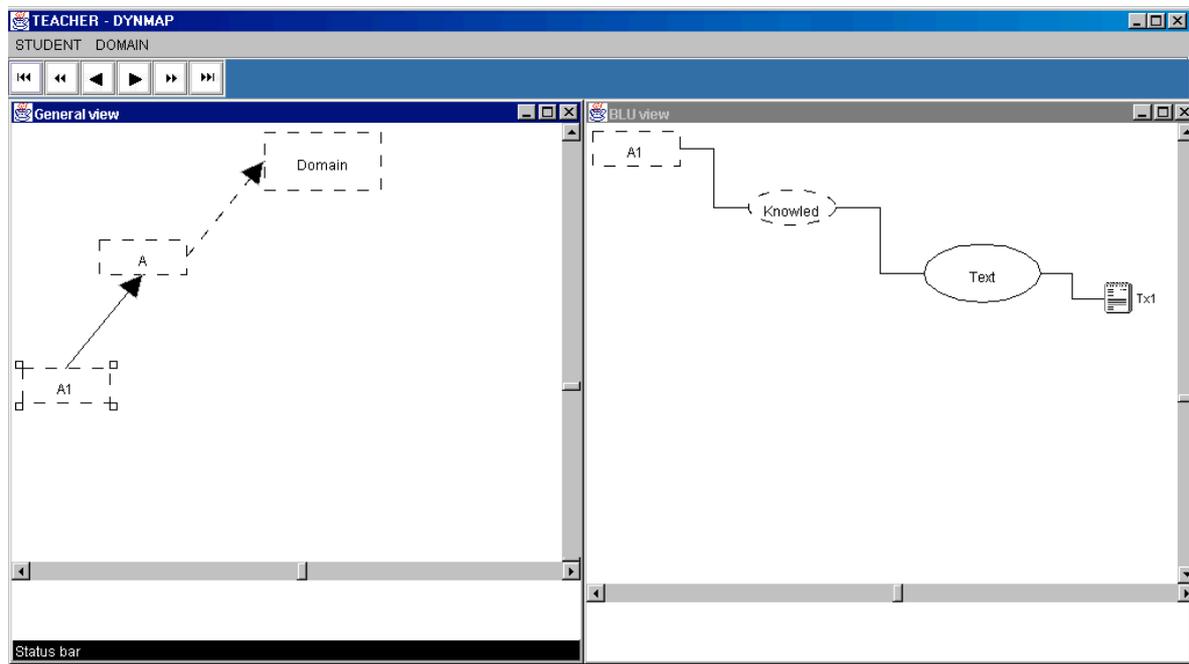


Figure 4. Snapshot of the SCM at the beginning of the session

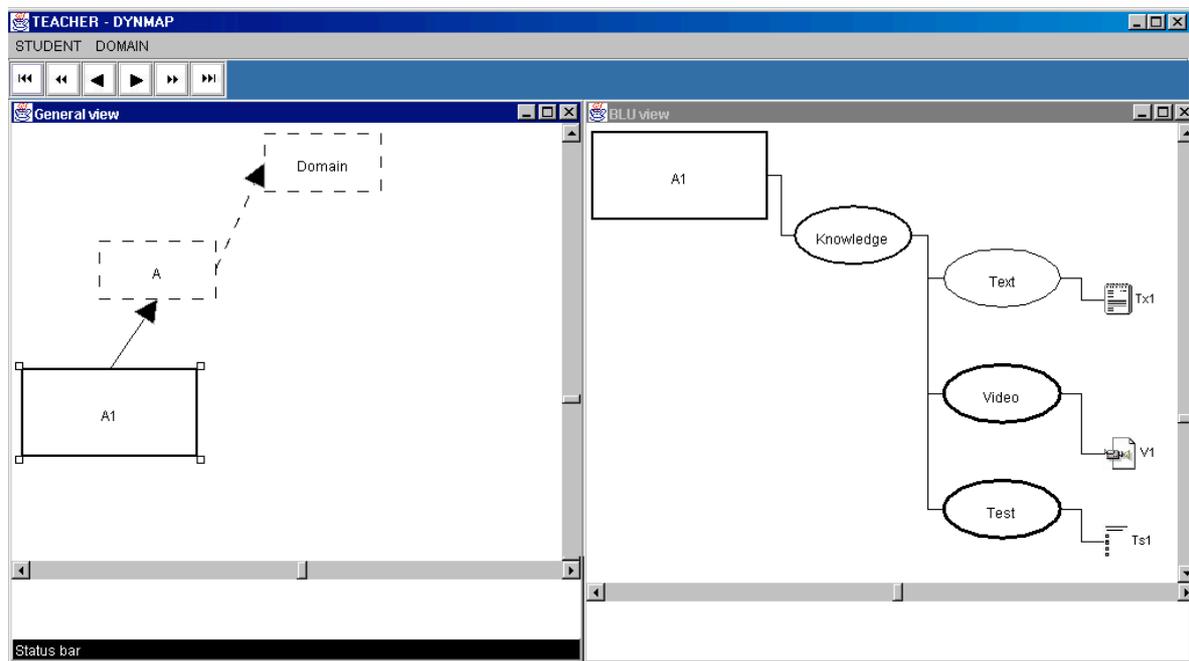


Figure 5. Snapshot of the SCM at the end of the session.

Figure 4 and 5 show the initial and final stage of one session. At the beginning of the session (Figure 4) the student is working with A1 BLU. All the nodes in the General view window have dashed borders because they correspond to not reached BLUs. As A1 is the selected BLU, the BLU view window (right side of Figure 5) displays its information organized in a tree. The student has read only one text (Tx1). At the end of the session (Figure 5) although the General view contains the same BLUs in the same spatial distribution, the characteristics of the nodes are different. Some nodes are bigger, for example A1, representing that the student knows more about the BLU. In addition A1 has a

continuous border showing that the BLU is already learnt. Also in the BLU view window some changes appear because the student has worked with more didactic resources. Note that the thickness of some nodes is different. For example *Text* node is thinner than the *Video* node because not all the texts have been shown unlike what happens with the videos.

The bottom part of the *Teacher-DynMap* has the note area. This will support communication between the teacher and the student.

4.4 Student-DynMap

The student viewer is simpler. Once the user is identified and authenticated, the Student's Inspector allows the learner to observe the concept map that represents the current beliefs of the system about his/her knowledge. The viewer for the learner is an application that can be executed at the same time as the ITS or independently. The interface shows the SCM in two panels (General View and BLU View) as explained above.

5.- Study: evaluation of graphical resources

Dimitrova *et al.* [6] argue that a medium where a student model is open for inspection should meet some criteria:

- *Understability.* The chosen representation manner must be easy to understand.
- *Effective inspection.* An effective representation must provoke inferential processes and help people to confront their problem comprehension.
- *Reducing the cognitive load.* Student model inspection is in its nature a demanding cognitive task and student model representations that reduce the cognitive load are favourable.

Focusing on the first criteria and in order to evaluate the validity of the graphical approach chosen for dynamically visualising the Student Model, a preliminary study was performed with one main aim: to see if the graphical resources selected to show different characteristics of the Student Model are adequate and easily understandable by teachers and students. The graphical resources included in the study were: *Size, Thickness, Line* and *Colour*. The study aimed to reveal potential problems of communication using them.

Participants. Two groups of people took part in the experiment: a group of 22 students from the Computer Science Faculty of the University of the Basque Country and a group of 22 teachers from the same college.

Procedure. A questionnaire was constructed to investigate participants' opinions about the meaning of each graphical resource and compare them with the significance initially set in DynMap (see table 1). It included four parts. The first one was composed of two graphic representations of two states and four multi-choice items, each one with four possible answers. The goal of the first part was to investigate what the changes produced in each graphical resource (e.g. different node size) suggested to the participants. It was possible to select one or more answers for each item. If the participant decided to mark more than one answer, s/he was asked to establish a priority between answers (1 to the more suitable, 2 to the second one, etc.).

Table 1. Meaning of the graphical resources in DynMap

Resource	Characteristic
Size	degree of knowledge of the content
Thickness	the content is enough worked or not (the student has used enough Didactic Resources)
Line	the student <i>has acquired the required level or not</i>
Colour	the student worked in that content <i>recently or not</i>

In the second part of the questionnaire five questions about a concrete state of a student model were asked. Two CMs were presented to the participants (see Figure 6). CM1 represented the whole set of contents to be transferred to the student, i.e. the domain

representation. Each node (rectangle) corresponded to a content. CM2 represented a concrete state of the student model during the learning process. The participants were asked which were the contents *already learnt*, the contents *more intensively worked*, the contents *more recently worked*, the contents *more accurately learnt* and the contents *not worked yet*.

In part three, participants were asked to establish their own criteria for graphically represent the four characteristics above mentioned.

Finally, in part 4 the participants had the opportunity to contribute with any suggestion.

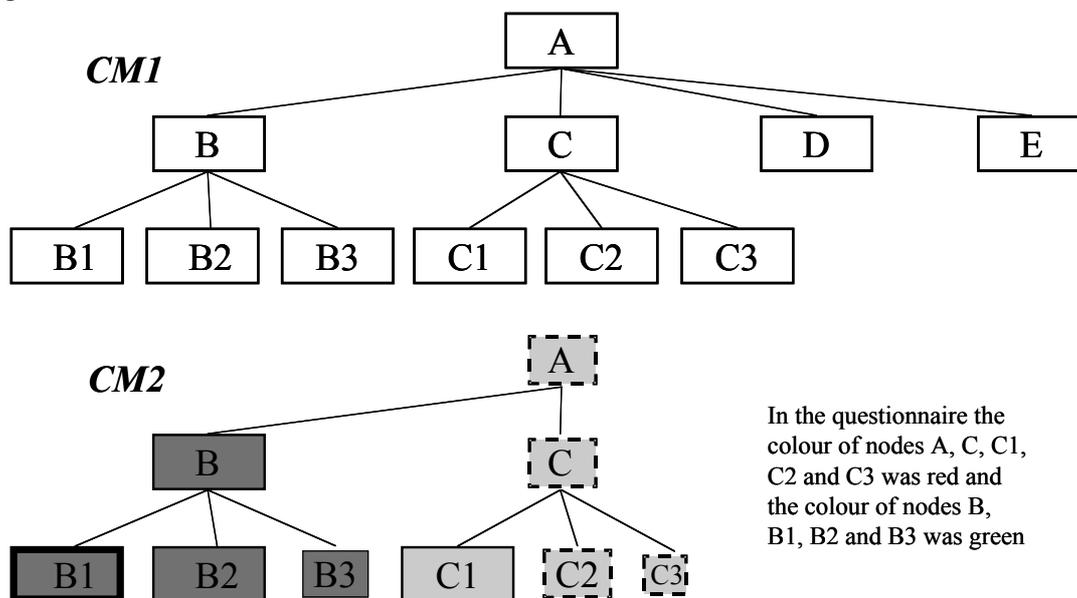


Figure 6. Domain (CM1) and student model's (CM2) contents representation

The students' experiment was conducted anonymously during a lesson and the teachers' experiment was conducted via e-mail. Nevertheless, if any teacher wanted to preserve his/her anonymity s/he had the opportunity to leave the answers in a physical mailbox. The questionnaire was electronically sent to 40 teachers and 22 of them answered it.

Results and discussions. Next the results and some conclusions are presented. They are grouped around the four basic graphical resources evaluated in the experiment.

Regarding the size of the node both groups of participants, teachers and students, understood it and considered appropriate the meaning proposed in DynMap (degree of knowledge the student has about the content). This mainly happened in those questions that did not mix it with other resources (first and third parts of the questionnaire). Table 2 shows the answers of teachers and students in those two parts. It can be observed that 100% of teachers (96% chose it as first choice and 4% as second), agreed with DynMap criteria. Also 77% of the students chose it as first choice, 10% as second and only 13% gave another answer. In the third part 73% of the teachers and 55% of the students agreed with the decision adopted in DynMap.

Table 2. Size resource

	First part			Third part	
	1 st choice	2 nd choice	Others	Size	Others
Teachers	96	4		73	27
Students	77	10	13	55	45

When *Size* appeared combined with other graphical resources (part two of the questionnaire) the degree of disagreement with the meaning in DynMap is considerable. It may be pointed out that the 60% of the teachers, instead of answering B, B1, B2 and C1

(nodes with bigger size), selected B1 as the best known content. The reason of this can be that B1 combines a big size node with a continuous thick line. It seems that a combination of different resources without a previous explanation of each one's meaning complicates the understanding of the student model.

The results obtained in the evaluation of *Line* and *Thickness* resources are quite similar. In both cases (see table 3 and 4) most of the participants, considerate that the resources are adequate for representing the same characteristic: if the content is or not enough worked. In fact, 77% (64%+13%) of the teachers and 74% (64%+10%) of the students (see table 3) and the 70% (60%+10%) of the teachers and 69% (64%+5%) of the students (see table 4) had the same opinion. In DynMap the assumption was to use the *Line* resource for representing when the content was acquired or not and the *Thickness* resource to symbolize when the content was enough worked or not. It seems that the difference between both characteristics is not clear for the participants; only a few of them chose *Line* (23% of the teachers and 36% of the students) for identifying whether the content was or not acquired, as it was implicit in DynMap. On the other part, meanwhile the majority of participants thought that *Line* was adequate for representing whether the content was or not enough worked, they would not choose it for representing this characteristic (table 3 shows that only 23% of the teachers and the 36% of the students made this selection).

Table 3. *Line* resource

	First part			Third part	
	1 st choice	2 nd choice	Others	<i>Line</i>	Others
T	64	13	23	23	77
S	64	10	26	36	64

Table 4. *Thickness* resource

	First part			Third part	
	1 st choice	2 nd choice	Others	<i>Thickness</i>	Others
T	60	10	30	55	45
S	64	5	31	64	36

Finally, table 5 summarises the results of *Colour*. DynMap used the colour for representing the time when the concept was worked. The red colour represented contents currently worked and the green colour represents contents worked some time ago. Only the 36% of the teachers and the 32% (27%+5%) of the students understood the resource, as it was implicit in DynMap. Although the 41% of teachers chose the colour as a resource for representing this characteristic, the majority of this percentage suggested us to use different shades of the same colour. Some participants also suggested that, without a previous explanation, it is difficult to associate the *Colour* resource with some characteristic. During the part two of the questionnaire more or less the same percentage of the participants agreed with the meaning of the colour in DynMap (30% of teachers and 18% of students).

Table 5. *Colour* resource

	First part			Third part	
	1 st choice	2 nd choice	Others	<i>Colour</i>	Others
Teachers	36	0	64	41	59
Students	27	5	68	18	82

In summary, considering the participants' answers and suggestions some conclusions can be pointed out:

- Meanwhile *Size*, *Thickness* and *Line* seems to be resources quite intuitive and easy to understand, *Colour* does not suggest anything without a previous explanation.
- Two characteristics included in the study are so close that it is difficult to understand the difference between them: the content is or not enough worked and the degree of achievement of the content.
- It is difficult to select any resource for represent the time when the content was worked; some participants suggest the use of flags or numbers.
- The combination of graphical resources adds an additional difficulty to the student model understanding.

- Although some resources are easy to recognise and understand a previous explanation of each one or a provision of patterns to compare with are welcomed.

6.- Conclusions

In this paper the authors have presented *DynMap*, a system for dynamically visualizing the Learner Model of an Intelligent Tutoring System (ITS) by means of Concept Maps. A Concept Map is a graphical way of representing knowledge. It seems that representing knowledge in a visual format allows one to better recognize and/or understand incoming information. Thus, the main goal is to facilitate students and teachers to better understand ITS outcomes, concretely the beliefs of the ITS about the student's knowledge.

DynMap uses the core of the Concept Map Editor (CM-ED) adapted by means of a template. It has two types of potential users: students and teachers. On the one hand, teachers can observe the dynamic evolution of the student and the state of the learner model at any time of the learning process. On the other hand, students are allowed to observe what the automatic tutor knows about their current knowledge.

As a future work some issues will be considered: the validation of *DynMap* as a mechanism to visualise the evolution of the students through the learning sessions, the creation of communication protocols between teachers and students, the representation of groups of students and the capacity of managing not only the beliefs of the system, but also the perspectives of the student and the teacher.

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