NATURAL LANGUAGE INTERACTION BASED ON AUTOMATICALLY GENERATED CONCEPTUAL MODELS

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Abstract: In this paper, we present a new form of interaction between students and free-text scoring tools based on the use of automatically generated conceptual models. Traditionally, students have worked with free-text scoring tools by typing free-text answers to the open-ended questions shown on the system's interface. Students could not personalize the aspect of the interface or visually acknowledge the level of progress they have made after answering the questions. In contrast, with this new form of interaction they are able to input natural language text and look at their generated conceptual model, which can be defined as a network of concepts and the relationships among them. In the conceptual model, each node has a background colour that indicates how well it has been understood by the student. The conceptual model can be represented in several formats such as concept maps, tables, charts, diagrams or textual summaries. The results of two experiments carried out with a group of students and teachers show how they like this new possibility.

1 INTRODUCTION

In the last decades, we have assisted to the flourishing of more and more e-learning approaches, which help students to follow courses with a flexible schedule, from any computer connected to Internet and at their own rhythm.

It can be observed how there has been a change in traditional education roles: teachers are relegated to a second plane, students have gained more control over their learning process and computers serve as a medium between students, knowledge and teachers. That way, students can log into on-line courses, read them and try to solve the exercises presented by the e-learning systems.

Regarding the type of exercises that the students can be asked to complete, there is the field of Computer Assisted Assessment (CAA), which focuses on the study of which exercises are more effective. In particular, one of the most challenging and interesting exercises are open-ended questions asked by free-text CAA systems as they involve higher cognitive skills and ask for natural language input (Pérez-Marín, 2007).

On the other hand, graph editors have also been produced to provide students with a visual representation of how well they have understood certain texts according to their student model (Dimitrova, 2003; Zapata-Rivera, 2004).

However, no natural language interaction was possible with the graph editors and, no student model was used in free-text CAA systems.

In this work, we propose the combined use of natural language input and a graphical representation of students' conceptual models. A student's conceptual model can be defined as a network of concepts and the relationships among them, which presents each node with a background colour. This colour indicates how well the concept is understood by the student.

That way, students can visually acknowledge the level of progress they have made after answering the open-ended questions in natural language. It has many benefits such as being able to track their evolution during the semester (Bull and Nghiem, 2002). Furthermore, students do not have to introduce the conceptual model using a graph editor. The conceptual model is automatically generated from the free-text answers typed to the scoring system in multiple representation formats: concept maps, tables, charts, diagrams or textual summaries. Students have also the possibility to personalize the interface according to their preferences.

This proposal is implemented in the Will tools (Pérez-Marín, 2007) that consist of: Willow, the

free-text CAA system; Willed, the authoring tool; Willoc, the configuration tool; and, COMOV, the conceptual model viewer.

Two experiments have been done to test this proposal. In both of them, the participants were asked to interact with the Will tools by using natural language to answer the open-ended questions asked by Willow and look at their generated conceptual model as shown by COMOV to graphically visualize the level of progress they have made.

The paper is organized as follows: Section 2 provides our definition of students' conceptual models; Section 3 describes the Willow and COMOV systems of the Will Tools; Section 4 reports the settings used and results achieved in the experiments performed with the Will Tools; and, finally Section 5 ends with the main ideas and lines of future work.

2 THE CONCEPTUAL MODEL

A conceptual model can be defined as a simplified representation of the concepts and relationships among them that someone keeps in his or her mind about an area of knowledge at a certain instant. Conceptual models have been extensively used for many different applications such as summative and formative assessment, knowledge elicitation and organization, etc.

The key point is to decide which concepts and relationships are going to be included in the model. The two traditional approaches are either to designate a group of experts to debate about it or to directly ask the students.

The problem of the first approach is that it is quite time-consuming because experts usually do not completely agree which the most important concepts for a certain domain are. Regarding the second approach, the quality of the concepts chosen is debatable. Moreover, in some cases, students are not even aware of all their knowledge (Sigel, 1999) and, in any case, the resulting list is subjective and depends on the people that have created it. Therefore, we have opted by a third option: to automatically identify the concepts so that the process is objective (independent of a particular human opinion) and faster (without needing a group of experts to create a common list of concepts).

A hierarchical structure of knowledge is considered as it is the most common organization of knowledge for people older than six years old (Inherlder and Piaget, 1964). According to this structure, not all concepts in the model have the same relevancy. In fact, three different types of concepts have been distinguished following the structure of traditional courses:

- Basic-concepts (BCs): Specific terms relevant for one or more topics. They are in the lowest level in the hierarchy, as they refer to individual instances. For example, *blanket*, *semaphore* or *process*. They are automatically extracted from the free-text students' answers. A BC can belong to one topic or to several topics but it only appears once in the conceptual model.

- Topic-concepts (TCs): Main issues inside an area of knowledge. They group several BCs and belong to a certain area-of-knowledge concept. For example, *concurrency* is a TC that comprises BCs such as *semaphore* and *process*. TCs are extracted from the names of the lessons of the agenda of the course as provided by the instructors.

- Area-of-knowledge-concepts (ACs): Main domains of knowledge that contains all the rest of the concepts. That is, they are the highest level concepts as they refer to groups of several TCs. For instance, *operating system* is an AC that comprises topic-concepts such as *concurrency* or *scheduling*. For each conceptual model, only one AC is allowed and it corresponds to the name of the course to model as given by the instructors.

Each concept, irrespectively of its type, has a confidence-value (CV) that reflects how well it is understood at any time. It is always between 0 and 1. A lower value means that the student does not know the concept as s/he does not use it, whereas a higher value means that the student confidently uses that concept. This CV is automatically updated as the student keeps answering questions according to a set of metrics (Pérez-Marín, 2007). The CV of a TC is calculated as the mean value of the CVs of the BCs that this TC groups and, the CV of an AC is calculated from the CVs of its TCs. Thus, just by looking if the AC has a high confidence value, it can be seen how well the whole course has been understood.

Three types of links have been distinguished according to the type of concepts that they relate:
Type 1, between ACs and TCs: A topic-concept belongs to one area-of-knowledge-concept. For example, the TC *concurrency* belongs to the AC *Operating Systems*. Type 1 links are extracted from the organization of the course provided by the instructors (i.e. which lesson corresponds to each course). A TC can only belong to one AC.
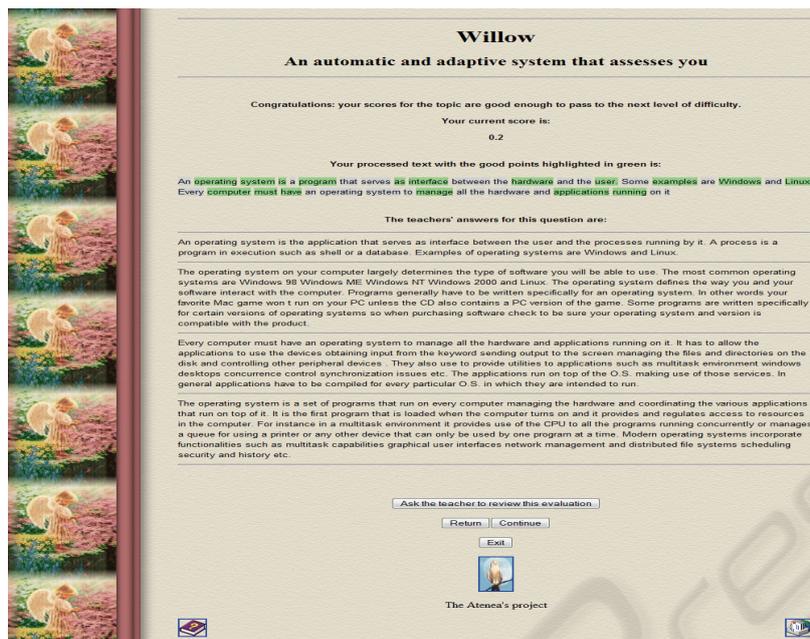
Figure 1: A snapshot of a generated feedback page.

− Type 2, between TC and BC: A basic-concept belongs at least to one topic-concept. It can also belong to several topic-concepts. For example, the BC *semaphore* belongs to the TC *concurrency,* whereas the BC *process* belongs to the TCs *concurrency* and *scheduling*. These relationships are important because they give us information about how the basic-concepts are grouped into topic-concepts. Moreover, for each BC that belongs to different TCs, they give us the student's ability to deal with the BC in the different contexts provided by the TCs. Type 2 links are extracted from the association between the basic-concepts used in the reference answers and the topics to which they belong.

− Type 3, between two BCs: A basic-concept can be related to one or more basic-concepts. For example, the BC *process* is related to the BCs *program* and *thread*. These links are very important as they reflect how BCs are related in the student's cognitive structure as they have been extracted from the students' answers.

Type 1 and 2 links are equal to all students as they are extracted from the structure of the course, whereas type 3 links are specific to each student as they are extracted from their answers.

It is also important to mention that each link has associated one or more linking words. The linking words join the concepts in the extremes of the link forming propositions.

The linking words for type 1 and type 2 links have been fixed as *"talks about"* (from the higher concept in the hierarchy to a lower concept) or *"belongs to"* (from the lower concept in the hierarchy to a higher concept). These linking words have been chosen as they serve to structure the knowledge and thus, capture the essence of these types of links. For example, *operating system "talks about" concurrency* or the other way around, *concurrency "belongs to" operating system* or*,* for type 3 links: *a program "is a kind of" software*.

3 THE WILL TOOLS

The Will tools are a set of on-line applications that make possible the automatic and adaptive assessment of free-text students' answers and the generation of the students' conceptual model from these free-text answers.

The outline of the procedure that allows the generation of the conceptual model is as follows:

1. The teacher or author of the course uses Willed, which is the authoring tool, to introduce the lessons of the courses to evaluate. In each lesson, there should be at least five questions of different difficulties and per each question, a minimum of three correct answers. The name of the subject is taken as AC of the conceptual model and, the name of each lesson is taken as a TC linked to the AC. Initially, the confidence-

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value (CV) of the AC and all TCs are reset to zero and stored as the basic scheme of the conceptual model for all the students.

2. An automatic script identifies the most important terms (concepts) from the texts introduced in Willed. These concepts are the BCs linked to the TC in which they have been found. As TCs, the CV of the BCs is reset to zero and stored in the conceptual model of each student.

3. Students register on-line to access Willow and start answering the questions introduced in Willed. Willow keeps track of the use of the BCs identified to estimate know well they are known by the student and update the CV in each particular student's conceptual model.

4. Teachers and students can access with their account to COMOV, to see the conceptual model as generated by Willow in multiple formats: concept map, table, bar chart, diagram or textual summary. They can access several times during the semester to follow the learning evolution of one particular student or the whole class.

As can be seen, Willow and COMOV are two key systems in the procedure. This is the reason why they are described in more detail in the following subsections.

3.1 Willow

Willow is an automatic and adaptive free-text scoring system. The interface has been designed to make easier the use of the system by students who do not have more Computer Science skills than using a web browser. It has Natural Language Support being able to process Spanish or English questions. The student can type his or her answer in natural language and, s/he receives immediate feedback as the one shown in Figure 1.

It is important to observe how the system does not only provide the numerical score but some kind of emotional interaction. It congratulates the student as s/he has been able to pass the question. Furthermore, it presents the justification of the score at the level of detail asked by the student. The default option is to show the processed student's answer and the correct answers provided by the teachers for this question. Nonetheless, the student could choose not to show the processed answer, or the references, or any of them.

If selected, the processed student's answer is shown with a background colour schema that indicates where the strong and weak points of the answer are. In particular, green background means a better match with the teachers' answers and thus,
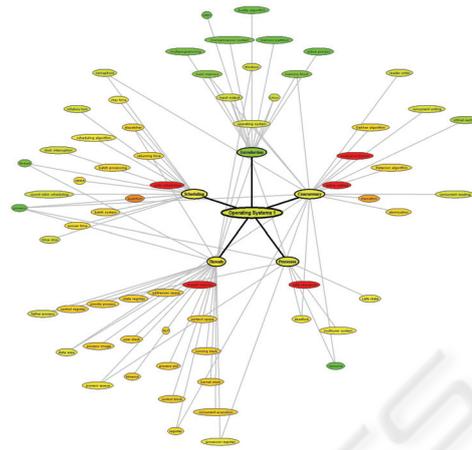

Figure 2: Sample of generated concept map.

a stronger point. Whereas, lighter green means a lower coincidence and gray indicates that it is irrelevant information for the question asked.

There are several correct answers provided by the teachers of the subject. This is necessary for the system given the internal behaviour of the scoring engine (Pérez-Marín, 2007) and also positive from the pedagogic point of view as having several paraphrasings of the correct answer helps the student to understand it and there is a better interaction between the student and the system.

Although there are some default values, Willow's pages can be personalized to change the background, font family, font size, etc. This is because, according to Pianesi et al. (2007), the more personalized the interface is, the higher the level of engagement and motivation to keep using the system. For instance, provided that the student is a child, more colourful and infantile backgrounds are available. Additionally, it is important to keep in mind the case of students with some kind of visual impairment or elderly people who need special features such as higher fonts.

The level of difficuly of the questions is adjusted to the student (Pérez-Marín, 2007). The end-of-session condition is decided by the student as a certain amount of time or questions, or dynamically by the system when the student has completed all questions of the higher level of difficulty.

3.2 COMOV

COMOV is the conceptual model viewer and can be accessed by students or teachers. Both of them can see the conceptual model of a particular student (in the case of the student, only his or her model) and of the whole class (taken as the average of the models of all the students).

The interface of COMOV keeps the line of Willow as it should be simple to be used by any student of any age and without Computer Science knowledge (more than using a web browser). It can be chosen how to display the conceptual model in order to keep promoting the possibility of personalization and having full control over the system. The possible representation formats are: concept map, diagram, table, bar chart or textual summary. Figure 2 shows the concept map representation of a sample generated student's conceptual model.

This representation is based on Novak's concept maps (Novak and Canas, 2006). A spider-like representation of the concept map has been chosen in which each node in the graph represents a concept: the AC is placed in the centre, and linked to it there are the TCs connected to the BCs.

The background colours follow the semaphore metaphor with red (lack of knowledge) to green (full knowledge) tones passing from orange-yellow (average knowledge). The colour is a representation of the CV associated to TC according to a scale in which 0 is associated to red, 1 to green, and there is a degradation of RGB components reducing red and augmenting green as the CV is higher.

That way, it should be easy to discern if the student has successfully assimilated the concepts exposed in the lesson just by looking at the background colours of the concepts in the map.

This is particularly important for the case of the AC as provided that it has a green background, it would mean that the student is ready to pass the course. Otherwise, some problems have appeared and they can be identified by, initially looking at TCs to see which ones are lacking and next, the BCs related to the non green TCs.

In addition to the information provided by the concepts and its hierarchy, links are very useful to detect misconceptions and lack of relationships. The misconceptions are detected whenever there is a link between two BCs that should not be related and thus, teachers should explain why. On the other hand, the lack of links between two concepts that should be connected denotes that students may understand each isolated concept but they have not recognized that they are related and thus, teachers need to reinforce the link between them.

This representation in form of concept map is particularly interesting whenever a global view of a particular student or the whole class is pursued, or to follow the students' conceptual evolution.

The conceptual model can also be represented as a conceptual diagram. It is a hierarchical diagram with the most important concept at the top and less relevant concepts below. In order to make the representation simpler, the relationships among the concepts are not explicitly represented, and the concepts are organized upon three types of rows. The first row is for the AC, the second row for the TCs and the next rows are for the BCs.

For representing the CV, the same background colour schema of the concept map is used. That is, the CV of the concept determines the background colour from red (CV=0) to green (CV=1) passing from light red, orange, yellow and light green. So, just by looking at the colour of the top row, the diagram gives a clear indication of the general level of understanding of the topics of the area-of-knowledge under study. Additionally, for the users who would like to have the exact numerical value of the CV for each concept, a tooltip has been included so that when they pass the mouse over each cell, they can see numerical value of the CV.

The other representations of the conceptual model included in COMOV are:

- Table: Each row corresponds to a BC and, the columns show the name of the concept, its weight indicating the relevance of the concept according to its frequency in the correct answers provided by the teachers, and the exact numerical values to justify its CV.
- Bar chart: In contrast to the rest of representations that show absolute values, the bar chart aims to compare BCs. Thus, it orders them according to the relative percentage that the CV of each of them covers regarding the total.
- Textual summary: It consists of three ordered lists indicating how well the ten most relevant concepts are known, and which the ten best and worst understood BCs are. In each list, the line represents a BC with its name, numerical CV and weight.

4 EXPERIMENTS

Two experiments have been done to find out how teachers and students like the use of conceptual models. Both of them have been in the Operating Systems subject of the Engineering degree at the Universidad Autonoma of Madrid and, they have followed the same procedure:

- Give a short introduction to the group about the Will tools and their possibilities (focusing on the use and interface of Willow and COMOV based on the conceptual model).
- Ask them to voluntarily use the tool designed for them (COMOV for teachers and students;

Willow for students). For students, the motivation was that it would have a positive impact in the final score of the subject.

− Solicit their opinion in an anonymous satisfaction questionnaire with close and open input items.

4.1 First Experiment

Willow was used by the first time in the 2005-2006 academic year. It was during 20 minutes in a class of 16 volunteer students (75% of the enrolled students in the subject) to study Willow's usability and to generate the first set of students' conceptual models. All students claimed that they like the system to review concepts and they would recommend it to other students.

The students rated the order of the questions with a 3.4 score in scale from 1 (dislike of the order of the questions) to 5 (like the order of the questions), and the difficulty of the questions with a 2.9 from 1 (easy) to 5 (difficult). These results are slightly better than in a previous experiment with a non-adaptive free-text scoring system in which random order was used (Pérez-Marín, 2007).

The feedback page generation options were fixed to have all the numerical score, the student's processed answer and the correct answers from the teachers. Besides, it was also selected to show the feedback of questions previously answered by failed. It was because we wanted them to have a full view of all the feedback possibilities.

Regarding the intuitiveness of Willow's interface, in the scale from 1 (not intuitive at all) to 5 (very intuitive), the average score provided by the students was 3.5. Moreover, they gave the system a 4.5 score in the scale 1 (very difficult to use) to 5 (very easy to use).

No student used the personalization options. We believed that it is because in the introductory talk that possibility was not mentioned and, they could use the system only during 20 minutes without time to find out it by themselves.

We did not allow students to enter COMOV because teachers had not still seen the models, and we asked a group of six teachers of our home university to use COMOV. They were positively surprised by the possibility of having an immediate representation of the students' conceptual models. In fact, all of them stated that they would like to use the Will tools in their courses and would recommend its use to other teachers to have more feedback about their students. One of the best regarded options was to have the class conceptual model and to see the general values for all the students.

Regarding the intuitiveness of COMOV's interface, in the same scale as above, the teachers gave a 3.8 score. Moreover, they highlighted the complementary views of the different representation formats of the conceptual model and, they had difficulties in one representation as the most illustrative of the real knowledge of the students. Eventually, there were more votes for the concept map. Furthermore, one teacher stated that he would like to have a view similar to the concept map but focused only on the concepts. This remark inspired us to build the conceptual diagram representation that was available for the second experiment.

4.2 Second Experiment

In the 2006-2007 academic year, we repeated the experiment with another group of students and teachers. In particular, we wanted to analyze how students use the Will tools (included COMOV as teachers have validated the last year generated models) during the whole semester.

24 students (41% of the enrolled students) volunteered to use the systems. The results of the experiment confirmed the conclusions drawn in the previous experiment. The students stated again that they considered the Will tools a great possibility to reinforce concepts.

It can be stated from the logs gathered in this experiment how students with more time to use the systems exploited the personalization features. In fact, from the 92 sessions registered in the system: in 91 sessions (98.9%) the text area size was changed, in 90 (97.8%) the font size, in 18 (19.6%) the background, in 8 (8.7%) the answer font colour, in 3 (3.3%) the font family and, once (1.1%) the statement font colour.

Regarding the feedback page options, in all the sessions they choose to have the feedback of questions previously answered but failed. In 86 sessions (93.5%), the feedback selected was the score, the processed answer and the references. While in the other 6 sessions (6.5%), the feedback selected was the score and the processed answer.

11 students (46%) used the new possibility of looking at the representation of their conceptual model during the semester. They reported by mail that they appreciated this extra feedback very much and, that it coincided with what they think about how well they knew the subject. Some comments provided by the students were *"I cannot imagine it was like that…it is amazing how I can easily see which concepts are clear and which ones are not"* or *"I think it is very interesting to help me know what to review. Thanks! "*.

When the students were asked why they like to see their conceptual model, some students' responses were: *"I want to see my progress", "To see which my weak points are"* or *"I am curious to see it, I think it is very interesting"*. Only one student said that he saw a problem with his conceptual model. It was that he felt embarrassed to see his complete lack of knowledge in Operating Systems. All the same, this student also indicated that he wanted to continue having the possibility of looking at the evolution of his conceptual model to see if he was able to improve his results.

Similarly as with the teachers, we asked the students which representation they considered the most illustrative of their real knowledge. It turns out that although they stated they have used all the representations as they considered them useful, from the review of the logs generated by COMOV, the conceptual diagram was the representation most visited followed by the concept map. In fact, it was the conceptual diagram of the whole class what more students reviewed.

Finally, it is also important to mention that the teacher of this subject confirmed the conclusions previously drawn from the last year survey to teachers. In particular, he stated that he considers very useful to have a system that provides him with more feedback about which concepts have already been understood and which ones should still be reviewed. Besides, he appreciated that it was not only at the level of each particular student but the whole class, giving a special relevance to the possibility of keeping track of the progress of his students by following the evolution of the students' conceptual models by using the concept map or conceptual diagram representations.

5 CONCLUSIONS

A new form of interaction between students and free-text scoring tools based on the use of automatically generated conceptual models has been presented in this paper.

The conceptual model has been defined as a graph in which the nodes are the concepts and the links are the relationships among these concepts. Three different types of concepts have been reviewed: AC which refers to the area-of-knowledge (subject) in general; TC which refers to each lesson in the subject; and, BC which refers to each particular concept treated in the lesson. Additionally, three different types of links have been distinguished: type 1 between the AC and each TC; type 2 between each TC and a BC (one BC can be linked to two or more different TCs); and type 3 between two BCs.

Each node has a background colour that indicates how well the concept is understood by each student (i.e. the confidence-value estimated by the system from the use of the concept in the student's answers). The colour follows a semaphore metaphor in which red indicates lack of knowledge; orange means average knowledge; and, green means full understanding.

The conceptual model can be represented in several formats such as a concept map with the AC at the centre and TCs around it connected to their BCs; a conceptual diagram focused on the concepts and following the same colour schema; a table in which the exact numerical values to calculate the confidence-value are shown; a bar chart in which relative percentages of how well the student knows a concept in comparison to the rest of the concepts are shown; and, a textual summary in which three ordered lists are shown to indicate how well the most important concepts are known and which the ten best and worst known concepts are.

The model is not introduced by the students using any editor. It is automatically generated from the free-text answers typed into a CAA system. In particular, the procedure that allows the automatic generation of the model has been implemented in the Will tools.

The Will tools consist of: Willow, the free-text CAA system; COMOV, the conceptual model viewer; Willed, the authoring tool; and, Willoc, the configuration tool. The students log into Willow and start answering the questions using the personalized interface with the options selected by them. The feedback page is generated from the assessment of the answer and according to the format chosen by the students. Willow also keeps track of how the students are using the concepts in their answers to update the conceptual model. The conceptual model can be seen in COMOV by teachers and students in the multiple representation formats explained above.

That way, students have been provided with the possibility of the personalization of the aspect of the system's interface. Moreover, students and teachers have been able to visually acknowledge in COMOV the level of progress the students have made after answering the questions in Willow.

Two experiments have been done to test how students and teachers like the new use of the conceptual model. It has been found that all of them consider this new possibility as interesting, highlighting that they can easily identify the concepts that should still be reviewed and the

concepts already assimilated. Additionally, the interface of Willow and COMOV has been rated as intuitive and easy to use.

Regarding which representation format of the conceptual model can be considered as the most illustrative of the real knowledge of the students, the teachers stated that all of the formats are complementary as they have different goals, but if they had to choose one, it would be the concept map. Moreover, it was suggested to create the conceptual diagram as a form of representation with the same colour schema that the concept map but focusing on the concepts and removing the links. In fact, the best considered representation format for the students was the conceptual diagram. Both teachers and students prefer to have the view not only particular to one student (in the case of the students only of his or her particular model) but the view of the whole class.

All students who used the Will tools during the second experiment passed the final exam and with scores higher than the students who did not use it (Pérez-Marín, 2007). From the logs it can be seen that students did not use the systems everyday but they worked harder the days previous to the exam to review more.

The best regarded option of the systems was to have immediate feedback. It can be seen that 100% chose to have the feedback of questions previously asked but failed and 94.5% chose to have all items available of feedback (numerical score, processed student's answer and correct answers provided by the teacher).

These results encourage us to continue working with the Will tools not only with students of engineering degrees but also with non-technical students. In fact, in the first semester of 2007-2008 academic year an experiment with students of English Language is being carried out at our home university. Furthermore, it is being studied to use the systems not only with Spanish students but with English ones in technical and non-technical subjects.

Other promising line of future research is to make the conceptual model more dynamic. That is, to make the conceptual model modifiable and not only inspectable. Students could gain more control over their learning process and improve the interaction with the system. For instance, they could be allowed to click on the concept marked as unknown in the model and getting instant information about it. The students could even be allowed to discuss the estimated CV of each concept with a natural language dialogue based on the conceptual model. On the other hand, Willow could also use the conceptual model to generate new

questions more focused on the problematic concepts identified in the answers.

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