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Design Overview of an Adaptive Computer-based Assessment System

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Summary

SPEBC, an adaptive computer-based assessment system, will provide initial, formative, and summative assessments. SPEBC will generate multiple-choice and open-ended questions adapted to the learners' background knowledge and external representations. SPEBC will generate personalized assignments and will use voting devices to capture the learner's answers in. Moreover, the personalization approach is based on the generation of personalized responses using for each set of answers a different kind of external representation. Previous studies about the use of adaptive systems and classroom communication systems in the classroom have shown to be effective.

Keywords

Adaptive Computer-based Assessment System, Classroom Communication System

Introduction

Nowadays, one of the challenges in the teaching-learning process is the incorporation of the recommendations derived from the theoretical advances. One of the pending issues is the attention to the diversity (Gardner, 2004). Furthermore, these recommendations foster the design of the assignments taking into account each student's understanding levels about the topics taught in class. The problem is how teachers can incorporate the background knowledge into the design of assignments or activities to do in the classroom, when they are working with groups of 35 students or more. This is the situation of many classrooms in Mexican public junior-high schools. At the same time, other research (Wang, 2006) indicates the importance of including formative assessment practices for the regulation of the learning-process. And in this way, to foster meta-cognitive attitudes in the learners that help them learn to learn (Aguilar, et al., 2006).

There are some problems related to computer-based formative assessment. These problems and the proposed solutions are given in Table 1. We propose in this paper the new adaptive learning system

called SPEBC (Sistema Personalizado de Evaluación Basado en Computadora), an adaptive computer-based assessment system, which has the following novel points: First, the tool combines a classroom communication system (CCS) and an adaptive computer-based assessment tool. The CCS allows a formative assessment of the learners when they are in the classroom. Moreover, the CCS will be modified in such a way that SPEBC will be able to identify each learner in order to generate a personalized assignment. Second, the tool will include a variety of assessment strategies, such as: Knowledge and Prior Study Inventory (KPSI) (Tamir, P. & Lunetta, V. N., 1978), factual questions (Questions starting with What, When, etc), and essays (Aguilar, et al., 2006).

SPEBC will support the continuous assessment processes and the learning regulation of Chemistry lessons for Junior-high schools. By using SPEBC we want to attend the class diversity. For this reason, SPEBC will generate assignments for learners, in real-time and in a personalized way. SPEBC will generate questions and personalized responses. By using SPEBC as a tool to attend the class diversity, teachers will be able to request the generation of questions and ask these questions to the learners, and learners will use their voting systems to send the answers in (Aguilar, et al., 2007a).

There are previous works about the development of adaptive assessment systems, these works are introduced in Table 2. We think that the development of an adaptive computer-based assessment tool and the use of a classroom communication system (Sharma & Khachan, 2005) can be an ideal tool to be used by teachers in order to include in the assignments design, each student's learning styles and to do a real-time evaluation of the learners' understanding levels (Aguilar, et al., 2006).

This paper is organized as follows: Second section gives a brief introduction about the assessment as regulation process. Third section presents an overview of the structure of SPEBC. Fourth section proposes an alternative for the mapping of learner's understanding levels and the grades of difficulty of the knowledge content. Fifth section presents effectiveness studies related to the proposed approach. And at the end of this work, conclusions are given.

Assessment as a Regulation Process

Assessment is a subject, which concerns to everybody: learners, teachers and the society in general. Socially, assessments are focused in summative assessments to determine the learners' mastering level about a given topic. However, less attention is paid to the assessment as a regulation process, being this fact an important element in the learning achievement (Black, 2003). Assessment means to be aware of the learners' specific needs and the elaboration of assignments, which allow the overcoming of the detected problems (Boekaerts, 1999). Assessment as a regulation process goes a step further than grading learners (White & Mitchell, 1994). There are three moments in the assessment process: at the beginning –initial-, during the instruction –formative- and at the end –

summative-. And all of them have as main goal the compilation of data in such a way that teachers and learners can take decisions about their teaching-learning process_(Aguilar, et al., 2007a).

Problems	Proposed Solutions
1. Systems provide multiple-choice questions. Some teachers argued that open-ended questions reflect a deeper understanding about a given topic (Sharkey & Murnane, 2006).	We propose to use multiple-choice questions but at the same time, the system will provide some other assessment strategies, such as: KPSI and essays. The system will generate automatically questions and answers but also the system will provide an option for the input of questions. These questions can be designed by teachers and they can decide when to use those questions. Multiple-choice questions will be graded by the system, and the essays will be graded by teachers.
2. Systems should develop more generalized skills of reading, writing, and critical inquiry in a collaborative way.	The inclusion of open-ended questions will allow the learners to develop skills such as reading, writing and critical inquiry. Collaborative work options will be provided. Teachers will ask the students to answer questions in groups. And class discussion will be fostered through the use of a CCS.

Table 1: Problems related to computer-based learning and formative assessment and the proposed solutions (Aguilar, et al., 2006)

The assessment as learning regulation, used to encourage metacognitive strategies, must be integrated during the whole teaching process. This is because the aim of learning regulation is to allow the detection of the learners' learning difficulties and the seeking of ways to overcome them in an autonomous way, generating personal learning strategies (Boekaerts, 1999). Additionally, assessment strategies must be varied, attending to the studied content and the moment in which they are applied. We decided to include: initial, formative and summative assessments. Initial assessment is done in order to gather diagnosis and prognosis information. Formative assessment is done in order to obtain information about the regulation of the teaching-learning process, identification of the obstacles that can be found in the learning process and the detection of topics that need to be reinforced. Summative assessment is done in order to determine whether or not a learner masters a given domain at the end of the course. It is important to emphasize that the difference among several kinds of assessment strategies is based on the assessment objectives. Moreover, one instrument can be used in different moments of the teaching-learning process (Jorba & Sanmartí, 1996) (Aguilar, et al., 2007a).

The Structure of SPEBC

The structure of the system consists of the following components, see Figure 1:

Questions-Answers Generator and Maintenance Module

The questions and answers generator will generate the questions and answers to be included in the assignment. This module was thought to cope with the combinatorial problem of the personalization factors. A first prototype is being implemented to generate questions about entities, processes, causes and conditions in chemical events. The generated questions start with What, Who, Why, Which and When. We are going to improve the first prototype taking in account approaches such as: Modeling (White & Fredericksen, 1998), problem solving (Nickerson, 1994), and cooperative learning (Lazarowitz & Hertz-Lazorowitz, 2003). And these will be provided as SPEBC's options. Each question will be taken from a text file, which can be a textbook, a paper, etc. Multiple choice questions will be implemented in such a way that the student will have to choose the correct answer. The questions and answers maintenance module controls the input, edition and organization of questions and answers (Aguilar, et al., 2006).

Research	**Type of Tool**	**Description**	**Adaptive?**	**Uses a CCS?**	**Constructivist and Formative Framework?**	**Proposed Tool**
Pear & Crone-Todd (2002)	computer-aided personalized system of instruction (CAPSI)	In CAPSI, the quality of the answer depends on how well it is argued as judged by the feedback it evokes from others.	YES	NO	Social Constructivist Tool	The system will attend the diversity, through the negotiation of the meaning of the questions and assignments and the coordination of activities among teachers and students, through the real-time assessment.
Peat (2002)	computer-based assessment	Provides results that are available to a large first year biology class. These materials include: weekly quizzes; a mock exam; quiz sections in tutorials; and special self-assessment modules (SAMS) .	NO	NO	Formative and Summative Tool	Supports in real-time the continuous assessment of the students and teachers. Personalized assignments promote the self-assessment. While the real-time assignments generation promotes the co-assessment of the students. The system will provide a feedback to teachers in such a way that they will be able to improve the teaching-learning process. The integration of the assessment and teaching, will

Research	Type of Tool	Description	Adaptive?	Uses a CCS?	Constructivist and Formative Framework?	Proposed Tool
						allow the teachers to improve their professional achievement (Black, 2003).
Alfonseca (2005)	Adaptive Computer Assisted Assessment	He proposes the evaluation of open-ended questions adapted to each student	YES	NO	Not Described	SPEBC will use traditional assessment and constructed response system and it will adapt the assignments to the learner's characteristics.
Proposed Tool	Adaptive computer-based assessment tool	A tool which combines a real-time assessment in the classroom and the generation of personalized assignments.	YES	YES	Constructivist and Formative Tool	

Table 2: Characteristics of previous works and characteristics of the posit tool (Aguilar, et al., 2006).

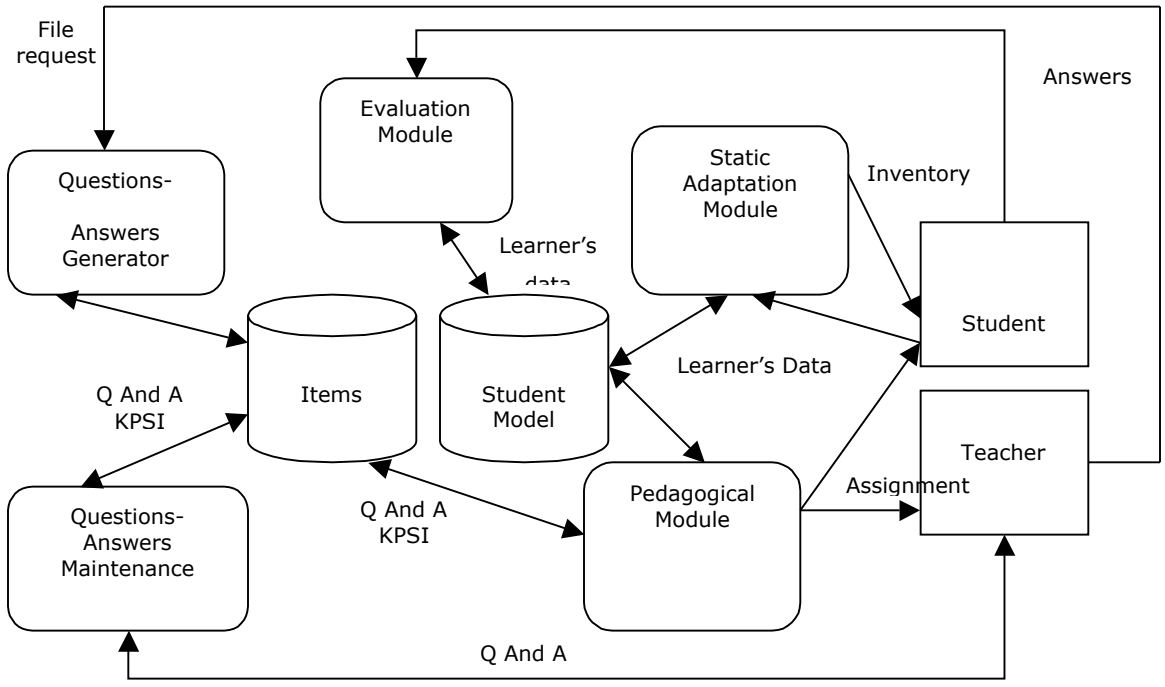


Figure 1: Design of the Adaptive Computer-based Assessment Tool (Aguilar, et al., 2006)

The structure of the Questions and Answers Generator is as shown in Figure 2.

Factual Questions and Answers Generator

Factual questions are those, which assess the learner's abilities to understand facts and processes. It is important to evaluate this ability because facts are important for thinking and problem solving (National Research Council, 2000). By generating these kinds of questions, we are trying to gather information about the learners' understanding levels about entities, processes, causes, and conditions of chemical events (Aguilar, et al., 2007a).

The factual questions generator divides the generation process into the generation of questions and the generation of personalized responses. The questions generation process is done as follows: Having as an input a text file, which contains the subjects to be studied in a text format, SPEBC will be able to generate questions in natural language. SPEBC will generate closed-domain questions dealing with knowledge under the specific domain of a course of Chemistry for a first-grade junior-high school. SPEBC uses text documents as its underlying knowledge source and combines various natural language processing techniques to extract and construct questions. Syntactic, semantic, and context processing will be done in order to generate questions. These techniques include: named-entity recognition (Humphreys, et al. 2000), conference resolution (Humphreys, et al. 2000), and rules, which match the Spanish grammar patterns (Aguilar, et al., 2007a).

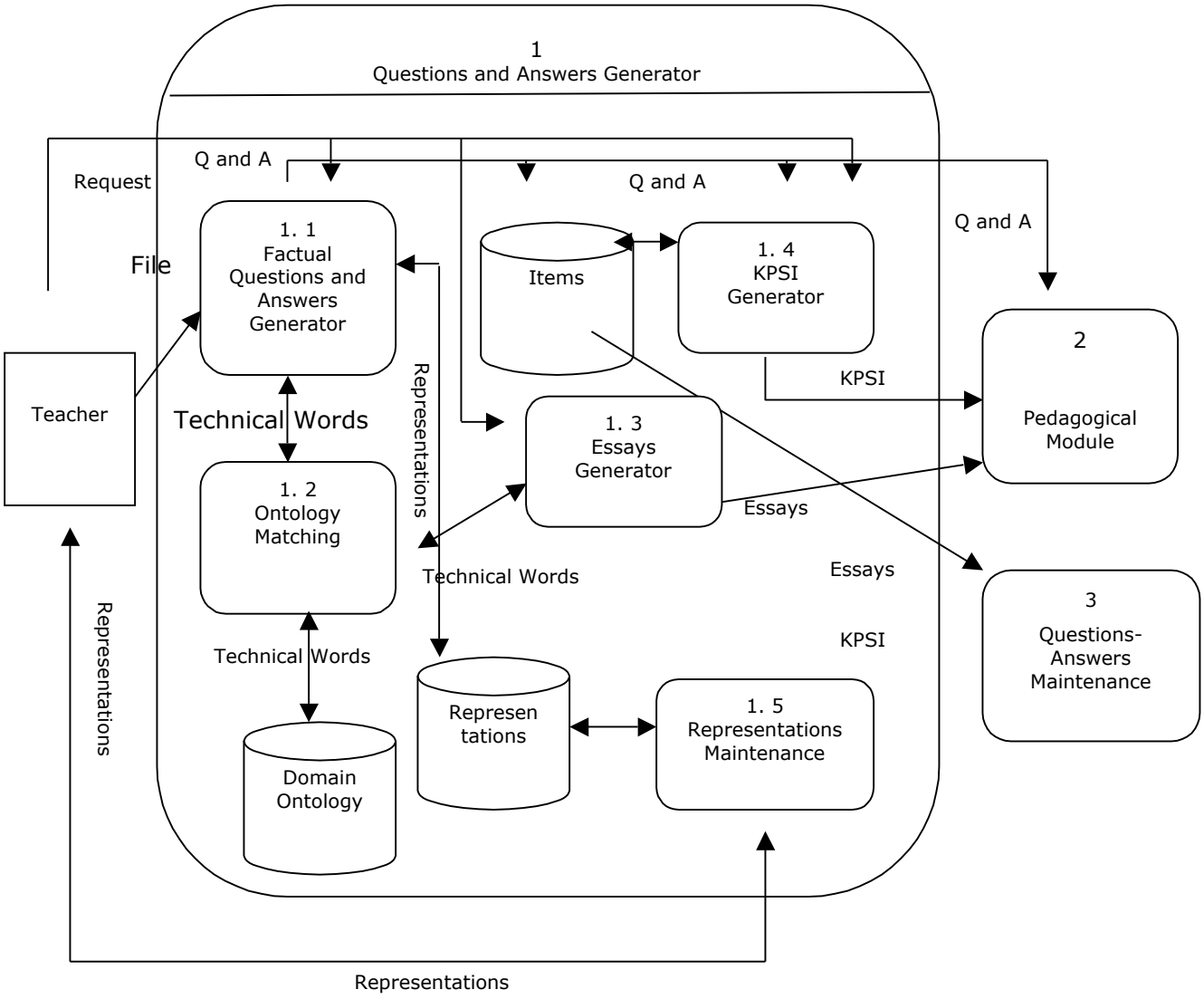


Figure 2: Design of the Questions and Answers Generator Module (Aguilar, et al., 2007a)

SPEBC will generate the answers for multiple-choice questions. One right and two incorrect responses will be generated. In order to generate personalized responses, we divided the personalization factors into: knowledge and learners' personalization factors. The knowledge personalization factors are:

1. Required knowledge: This refers to the knowledge that a learner should know before studying a given topic.

2. Representation: This refers to the way in which the knowledge is introduced to the learners. For example, the representation of the concept of water can be given in natural language, through a draw of the water molecule or using its chemical formula (Giere & Moffat, 2003). Figure 3 shows

an example of the representation types to be included in SPEBC. We classified these representations in writing, figure and formula, respectively.

The learners' personalization factor to be included in the design of SPEBC will be the background knowledge. This personalization factor allows the modeling of the learners' knowledge. Required knowledge and background knowledge refers to the same knowledge but they can be seen from the point of view of the knowledge and from the learner. At this point of the present research, we are going to consider the straightforward relation between required knowledge and background knowledge, and we will use different representations to personalize the responses of multiple-choice questions (See Figure 4).

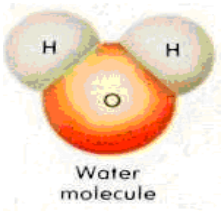
Water  **H_2O**

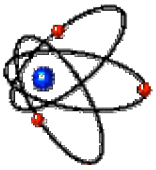
Figure 3: Different Representations of the Water concept (Aguilar, et al., 2006)

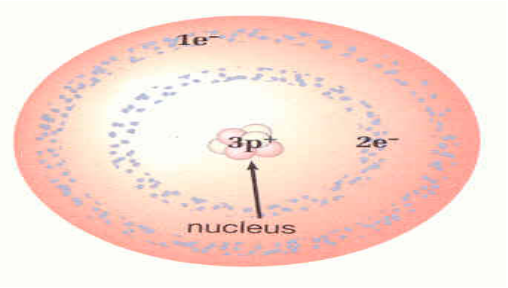
The responses to the questions which start with what, how, why, and which will be personalized using the three different types of external representations. The answers to the questions, which start with who, when, and where, are going to be introduced to the learners using only the writing external representation type, this is because the answers are more specific. The personalization process of the responses consists of introducing the learners' responses in three different forms of representations (See Figure 4). These representations will be saved on a database, and there are two ways of incorporating the responses for multiple-choice questions, these are: manually and automatically. The manual process consists of the input of each response using a keyword for a given representation, SPEBC will process the questions and the keywords of the responses and it will paste the related representation. The automatic process consists of the generation of multiple responses. When factual questions are generated the correct response is also generated. In order to generate two wrong answers SPEBC will search in the representations database related keywords and SPEBC would substitute these keywords with their correspondent representations (Aguilar, et al., 2007a).

Concept-oriented Programming (Savinov, 2006) represents an available alternative to implement a computer-oriented representation of the world. We are referring to such world model as ontology. This implementation approach pursues the determination of the construction of the ontology and content. Ontology generally describes: individuals, classes, attributes and relations. Concepts integrate the individuals of the ontology. Concepts are classified into types, which define the ontology's classes. And attributes and relations are described in each concept (Aguilar, et al., 2007a).

Generated Question

Which one is the Dalton's atomic





Response 1 **Response 2** **Response 3**

Figure 4: An example of multiple-choice questions and answers personalization (Aguilar, et al., 2006)

KPSI Generator

Knowledge and Prior Study Inventory (KPSI) (Tamir & Lunetta, 1978), is a self-assessment inventory, which allows the assessment of the learners' prior knowledge. This inventory helps teachers gather information about the learners' perception about their own understanding level with regard to the topics that they will teach. Also, this inventory will help learners understand the learning objectives to be reached in the teaching-learning process. KPSI will be used as an instrument to assess learners understanding before and during the teaching-learning process. KPSI will be introduced to the learners as multiple-choice questions. Questions to be included in a KPSI will be factual questions and these will be generated (Aguilar, et al., 2007a).

Essays Generator

Essays instruments will be included in SPEBC in order to encourage the learners to develop their ideas about some topic. And this will foster the development of learners' writing and arguing skills. SPEBC will have as an input a text file, which can be a textbook, a paper, etc. And from this text file, SPEBC will select some technical words that will be given to the learners in order to write an essay. Concepts, which will integrate the ontology, will allow the matching of technical words defined in the text file given as an input with the technical words defined in the system (Aguilar, et al., 2007a).

Pedagogical Module

The pedagogical module controls the selection of questions and help teachers in the planning of the generation of assignments. The questions to be included in each assignment will be based on the right and wrong answers given by the student during a session. Teachers can identify to the advanced students who can help the less advanced ones. In planning the generation of assignments, a number of decisions must be made regarding exactly how the assignments will be administered to the students. This will include information such as which study unit will be assessed, which item bank will be used, the order in which they will be administered, etcetera. The pedagogical module accesses the base of questions in order to select which will be the questions to be included in the assignment. The pedagogical module accesses the student model in order to gather the learner's personal characteristics. The questions selection process is based on background knowledge and grades. The factor to be considered by the pedagogical module, when the system is initialized, is the background knowledge. Background knowledge will be updated dynamically based on the student's right and wrong answers given in real-time during a class and with the assignments' evaluation (Aguilar, et al., 2006).

Evaluation Module

The evaluation module will grade the learners' answers. The evaluation module will save the learners results on the student model. By using an evaluation module, the system will grade the learner's answers, pinpointing the places where the learner had difficulties (Aguilar, et al., 2006).

Static Adaptation Module

The Static adaptation module controls the application of psychological tests and background knowledge evaluations. The static adaptation module will introduce to the learners background knowledge evaluations and external representations questionnaire. This module will initialize the student model with the learners' background knowledge and they preferred external representations (Aguilar, et al., 2006).

Student Model and Items Database

The student model will reflect the static and dynamic adaptations. The personalization factors allow the system to create a learner's model and based on this model, the learners can learn in an adaptive teaching-learning environment. The student model will be updated with the learner's changes, in this way the system will be able to control the changes in background knowledge after each assignment or class. The student model includes data such as: student' name and ID, the date and time of a test administration, the answers given to each item, whether those answers were correct or incorrect,

grade, etcetera. In the items database data such as question, answer, unit, grade of difficulty, KPSI inventories, etc. will be saved (Aguilar, et al., 2006).

Mapping the Understanding Levels to the Grades of Difficulty

One of the major points related to the implementation of SPEBC is the mapping between the learner's understanding level and the grade of difficulty of the knowledge content. The learner's understanding level can be classified into the learner's understanding level with regard to the question and the learner's understanding level with regard to the representation. In order to determine for each learner the understanding level of each representation, learners will answer a questionnaire. The results of this questionnaire are understanding level quotients. The values of these quotients are: 1 for easy, 2 for intermediate and 3 for difficult.

The grade of difficulty of the knowledge content can be classified into the grade of difficulty of the representations and the grade of difficulty of the questions. The grade of difficulty of each representation will be record by computing the average of the learners' right and wrong answers and their average answer time. Questions are classified into grades of difficulties. There are two grades of difficulty, these are: basic and advanced. Questions starting with Who, When, What and Which belong to the basic level and questions starting with How and Why belong to the advanced level.

In order to determine the learner's understanding level for each question, we are going to consider two factors: the learner's right/wrong response and the learner's answer time. The following cases are going to be considered:

1. If the learner's answer was right

   This will indicate that the learner understood the question and the representation in which the question was presented. And the answer time will be recorded to determine what is the learner's average answer time.

2. If the leaner's answer was wrong

   a. The causes can be the following:

   The learner did not understand the question

   In this case, SPEBC will provide help to the learner. This help will consist of deploying the context in which the question is situated.

b. The learner did not understand the representation in which the answers were given

In this case SPEBC will try to introduce another question. This question and its answer will be presented using another type of representation. This representation will be selected with a lower grade of difficulty for the learner. SPEBC will use the information obtained from the external representation questionnaire to select an easier external representation. In the case that the original question were given in the learner's easiest representation and even that the learner does not understand the representation, SPEBC will use other learners' information. Other learners and the learner must have the same characteristics. And the other learners must get a right answer. SPEBC will choose the path that other learners followed and it will introduce the next question and answer based on the information compiled in that search. If the learner gets one more time a wrong answer SPEBC will determine that the learner does not know the answer. SPEBC will grade the answer like a wrong answer and it will proceed to the c) point.

c. The learner does not know the answer

When a learner does not know an answer, SPEBC select the next question with a lower grade of difficulty. For example, if the previous question was an advanced question, and the learner got a wrong answer, SPEBC will select a basic question. SPEBC may generate more than 2 alternative questions for the same topic, when this happen, SPEBC will have to determine among the who, when, which, what questions which question to introduce to the learner. SPEBC will do this, the first time that the system is used, by selecting the question randomly. And the next times when the system has been used, by searching other learners' information who answered correctly the given question. The other learners and the learner must have the same characteristics. SPEBC will introduce to the learner the same type of question that other learners' answered correctly. In the case that SPEBC has no record of other learners, SPEBC will choose the type of the next question randomly. In the case that the question which answer is unknown by the learner is in the same level of difficulty, SPEBC will choose randomly or by searching other learners' information, as explained above.

Effectiveness of the Proposed Approach

Empirical studies about the effectiveness of adaptive systems have shown that adaptive navigation support can increase the speed of navigation (Kaplan, 2002) and learning (Brusilovsky, 2002), whereas adaptive presentation can improve content understanding (Boyle, 1999). More over, the results of previous studies about the effectiveness of the incorporation of a CCS in the classroom indicated that the students were more engaged in learning when CCS was utilized. While teachers believed that the CCS positively impacted their teaching (Godfrey, 2006).

Conclusions and Further Research

The rapid progress made in the use of computers in the classroom for all educational levels in the world, requires developing systems which effectively help teachers to improve the teaching and learning process. The design of the system considers this, through the real-time students' assessment and its adaptive approach. One of the aims of the present research is to support teachers in the assessment process as regulation in order to help them foster in the learners metacognitive attitudes. We think that SPEBC will be a new actor that will influence the educational process. The challenge for teachers is the incorporation of SPEBC in such a way that this new actor can be a real support in the improvement of the teaching-learning process. Some of the challenges to be faced in the development of SPEBC are the generation of questions and personalized answers based on the grade of difficulty, its design and its implementation. Further research will be focused in completing the implementation of the first prototype of the factual questions generator. Two versions will be implemented, one version will generate factual questions and answers without the adaptation of background knowledge and a second version will include the adaptation process. We will do the evaluation of the system effectiveness by establishing a comparison between these two versions. At the same time, we will evaluate the challenges and opportunities generated in the classroom, when different assessment strategies are used. And with this information we also will generate alternatives for teachers.

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