

Learners and Knowledge: A New Personalization Factor Perspective for Adaptive Computer-based Assessment Systems

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Abstract: This paper introduces a work-in-progress about the development of the Adaptive Computer-based Assessment System called SPEBC (Sistema Personalizado de Evaluación Basada en Computadora). Teachers by using SPEBC, as a tool to attend the class diversity, will be able to request the generation of assignments and learners will use their voting systems to send the answers in. The adaptation process of the proposed work is based on the creation of the knowledge and learner's models, being the contribution of this paper the incorporation into these models, the required and background knowledge, grade of difficulty and external representation types. SPEBC will generate multiple-choice and open-ended questions, personalizing the responses according to each learner. The learner's personalization factors are: background knowledge and external representations. The knowledge content personalization factors are: required knowledge and external representations. The external representation factor is divided into understanding level, grade of difficulty and representation type.

Introduction

This paper introduces a work-in-progress about the development of the Adaptive Computer-based Assessment System called SPEBC (Sistema Personalizado de Evaluación Basada en Computadora). (Aguilar, et al. 2006). SPEBC combines an adaptive assessment system with a classroom communication system (CCS) (Sharma & Khachan, 2005). Teachers by using SPEBC, as a tool to attend the class diversity, will be able to request the generation of assignments and learners will use their voting systems to send the answers in. SPEBC will check the answers and will deploy a histogram with the assessment results. In this way, teachers will be able to evaluate the learners understanding level in real-time. Furthermore, teachers will be able to take decisions about the actions to be taken in order to improve the teaching-learning process, for example, teachers and learners will be able to use the assessment results for their own teaching and learning process regulation. SPEBC will provide initial, formative, and summative assessments. The assessment strategies to be included are: Knowledge and Prior Study Inventory (Tamir & Lunetta, 1978), factual questions and essays. SPEBC will generate multiple-choice and open-ended questions, personalizing the responses according to each learner and knowledge content.

In the design of SPEBC, we have considered the interactions between the learners' knowledge and the knowledge to be learned. This interaction is fundamental from the Constructivist perspective for the teaching and learning of sciences (Driver, et al. 1999). Moreover, some authors have attracted the attention to the diversity of the forms in which the knowledge content can be expressed by teachers (Marquez, et al., 2003). A concept can be presented using different forms (text, graph, draw, etc). These forms of presentations are called external

representations or semiotic representations. Also, it is important to teach learners the identification of different external representations, their characteristics, and usefulness (Tamayo, 2006). The incorporation of this perspective implies the conception of the communication in the classroom like a multimodal communication, in which we can find different forms of communication (Kress, et al. 2001). As Kress said, “the relation between form and meaning is crucial if one wishes to develop a theory of meaning in which individuals are real makers of meaning” (Kress et al., 2001:5).

There are previous works about the development of adaptive assessment systems such as those of Alfonseca, et al. (2005) and Pear, et al. (2002). Alfonseca (2005) proposes the evaluation of open-ended questions adapted to each learner. The adaptation process done by Alfonseca (2005) is based on the determination of personal features and preferences, learning styles and previous knowledge. The adaptation process to be done by SPEBC is based on the creation of the knowledge and learner’s models, being the contribution of this paper the incorporation into these models the required and background knowledge, understanding level, grade of difficulty and external representations types. On other hand, Pear (2002) implemented a constructivist tool, called CAPSI (Computer-Aided Personalized System of Instruction) in which the quality of the answer depends on how well it is argued as judged by the feedback that are evoked by others. SPEBC as well, will attend the diversity. However, the attention to the diversity will be done through the negotiation of the meaning of the questions and assignments and the coordination of activities among teachers and students. Furthermore, the diversity will be attended through a real-time assessment. A comparison between previous researches and SPEBC is summarized Table 1. The development of this kind of systems is necessary to support the use of new technologies in the teaching-learning process, and this is an important issue in Mexico, where teachers often have classes of more than 30 students.

Researches	Type of System	Abstract Models	Personalization Factors	Sub-factors
Alfonseca (2005)	Adaptive Computer-based Assessment	Student Model	Personal Features and preferences Learning Styles Background knowledge	User’s language (English or Spanish) Age (Young or adult) Novice or advanced
Pear & Crone-Todd (2002)	Adaptive Computer-Aided Assessment	Student Model	Background Knowledge	Not described
SPEBC (proposed work)	Adaptive Computer-based Assessment	Student Model Knowledge Content Model	Required Knowledge Background Knowledge External Representations	Grade of Difficulty Representation Type

Table 1: Comparison among previous researches and SPEBC

The posit models try to provide a better way for the representation of the knowledge content and the record of the learners’ characteristics. These models were established in order to use them in the development of SPEBC, an adaptive computer-based assessment system. The knowledge content model and student model will be useful in the determination of validity and reliability studies.

This paper is organized as follows: Second section introduces the models and the dynamic and static adaptations of the personalization factors to be considered in the design of SPEBC. Third section gives the usefulness of the interaction between knowledge content model and student model. And at the end of this work, conclusions are given.

Models and Personalization Factors

A reference model to support adaptive Hypermedia Authoring has been previously developed (Wu, et al., 1998). Wu proposes the creation of a reference model for the learner, teacher and knowledge. We go a step further adapting such model to a personalized assessment system. The student model and knowledge content model will be updated statically and dynamically in order to allow the system to do the adaptation process. The static adaptations to be done

by SPEBC are as follows: SPEBC will perform static adaptations in order to identify the learners' characteristics and initialize the system. Learners have to answer a Knowledge Prior Study Inventory (KPSI) (Tamir & Lunetta, 1978) in order to make possible for SPEBC to determine their background knowledge about a given topic. SPEBC will determine learners' initial type of external representations through the application of a questionnaire, which result is the learner's easiest, intermediate and difficult external representations. Also, learners have to answer a questionnaire about their personal data to create their profile. SPEBC will do dynamic adaptations of the knowledge content and learner's personalization factors. Dynamic adaptations are those done during the interaction between learners and the system. These are introduced below.

The factors for the knowledge content are as follows:

1. Required knowledge: This factor records the knowledge that learners have to know before SPEBC asks questions about a given topic. Teachers will define the required knowledge hierarchy based on the course syllabus. Figure 1 shows an example of the themes hierarchy to be studied by learners in a first grade of Chemistry of a Mexican public secondary school. SPEBC will be able to determine whether the required knowledge has been previously assessed by doing the following process: For each theme to be evaluated, teachers will define key concepts. When teachers request to SPEBC the generation of assignments, they will introduce a text file from which questions will be generated. SPEBC will generate questions by using the text file 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), coreference resolution (Humphreys, et al. 2000), and rules, which match the Spanish grammar patterns (Aguilar, et al., 2007). Teachers have to capture the key concepts related to that text file content. SPEBC will check whether the previously defined key concepts (required knowledge) have been already evaluated. SPEBC will deploy a message to inform teachers that there are some topics that have not been evaluated and it is necessary to evaluate them first or, that the assessment of the present topic can be done.

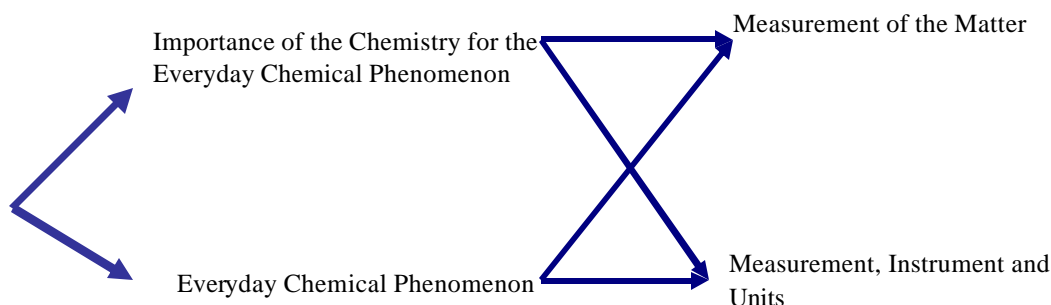


Figure 1: Knowledge content precedence for the first year of a Chemistry course of Mexican public junior high schools

2. External representations: A given concept can have several external representations (Giere & Moffat, 2003). For example, the concept of nicotine can have as external representations: the word nicotine, the figure of the nicotine molecule and its chemical formula (See Figure 2). SPEBC will generate the responses for the multiple-choice questions as follows: Figure 3 shows one question and three alternative responses given using the same representation type. SPEBC is going to generate one question and it will generate three sets of answers, one set of answer for each representation type. However, teachers will be able to choose what are the type of representations to be used by SPEBC to generate responses. This can be done at the first time when the system is used or during the execution of SPEBC. In the first case, SPEBC will generate responses using only the pre-configured type of representations. In the second case, teachers will be able to select the type of representations to be used by SPEBC in the generation of responses for each question, in such a way that different questions will be introduced to the learners using different types of representations, based on

the teacher's selection. The presentation of different external representations for a given concept is very important in science education because a given representation shows specific characteristics of the concept.

The external representation factors are:

- Grade of difficulty. This is represented using a number (1-easy, 2-intermediate, and 3- difficult), which is assigned based on the average of the understanding levels of the learners which belong to the same class.
- Type of representation: In the domain of Chemistry (See Figure 2), we divided the types of representation into: Writing, figure and formula.

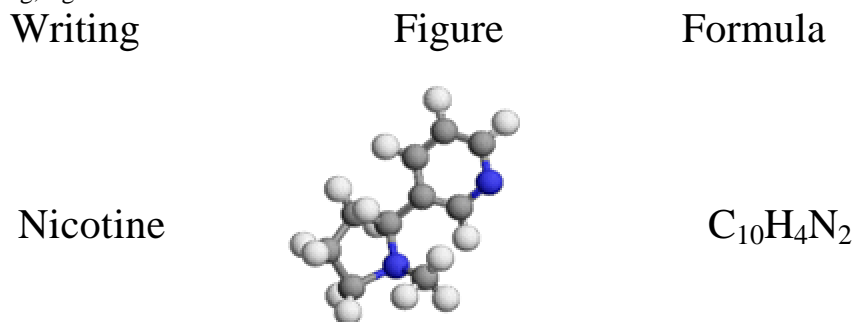


Figure 2: Different external representations of the nicotine concept

Generated Question

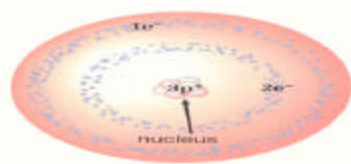
Which one is the Dalton's atomic model?



Response 1



Response 2



Response 3

Figure 3: An example of multiple-choice questions and answers personalization (Aguilar, et al.,2006)

The knowledge content model will be used to record data about each question to be included in the assignment. SPEBC will check the learners' answers (right or wrong), infer the understanding level of each learner (1, 2 or 3), and select the representation type (Figure, writing and formula) chosen to answer each question. After determining the type of representation for a given question, also the level of difficulty will be determined for that question. In order to determine the grade of difficulty for the next question, SPEBC will consider three factors: the learners' grade of difficulties compiled through the external representation types questionnaire, the right and wrong answers given by each learner, and his or her answer time. For example, if a learner got a wrong response, SPEBC will assign to the grade of difficulty, a number from 1 to 3 based on the answer time and based on the results of the external representation type's questionnaire.

The learner's factors to be incorporated in the student model are:

- Background knowledge:** This factor indicates how much a learner knows about the domain to be learned. Background knowledge will be represented with a tree data structure and this data structure will contain an extra variable to indicate with a number (0 or 1) whether the learner does know or does not know that topic. SPEBC will adapt the learner's background knowledge dynamically based on the learner's right and wrong answers. Moreover, learners may know the right answer for a given question. However they may not understand the representations in which the responses were presented, therefore, in order to cope with this

problem, SPEBC will introduce at first the learner's easiest external representation and SPEBC will increase the grade of difficulty of the representations by introducing to her or him some other representation types.

2. External representations: This factor indicates what is the history of the learner's used external representations and in this way, together with the learner's data compiled through the application of the external representations questionnaire, the system will infer the next type of representation to be introduced to the learner. The external representation factor has also some other factors, these are:
 - a) Understanding Level. This is represented using a number, which indicates the learner's understanding level in the same way in which the grade of difficulty of the external representations of the knowledge content personalization factor is recorded.
 - b) Type of representations: The values for the types of representations are: Writing, figure, or formula. And the learner's representation type will be updated dynamically based on the representation types selected by the learners for each right question.

Usefulness of the Interaction between Knowledge Content Model and Student Model

The knowledge content factors were determined in order to do reliability and validity evaluations of the generated questions. Reliability refers to the consistency of scores obtained by the same person when they are reexamined with the same test on different occasions, or different sets of equivalent items, or under other variable examining conditions. The validity of a test concerns what the test measures and how well it does so (Anastasi & Urbina, 1997). The data saved on the student model and knowledge content model will be used by SPEBC to do qualitative and quantitative analysis. Qualitative analysis includes the consideration of content validity, as well as the evaluation of items in terms of effective item-writing procedures. Quantitative analysis includes principally the measurement of item difficulty and item discrimination (Anastasi & Urbina, 1997). Table 2 shows an example of the learners' data to be saved on the student model. The student model will contain the learner's characteristics in order to do the adaptation process, however, Table 2 only shows the data required to do the reliability and validity evaluations. Table 3 shows an example of the data to be saved on the knowledge content model. By saving these data we are trying to establish an agreement between two independently derived sets of score, in such a way that they can be expressed in terms of a correlation coefficient. Thus, if the top-scoring individual in variable 1 also obtains the top score in variable 2, the second-best individual in variable 1 is the second-best in variable 2, and so on down to the poorest individual in the group, and then there would be a perfect correlation between variables 1 and 2. Such correlation would have a value of +1.00 (Anastasi & Urbina, 1997). From the data saved on the knowledge content model, SPEBC will infer information to do reliability studies. We are going to try to establish a correlation coefficient by establishing an agreement between two independently sets of scores, that is to say that, each question will be applied to two groups of learners and a given question must have the same percentage of right answers in both sets of scores.

Learner ID: 1005516				
Question ID	Type of Representation	Type of Answer	Understanding Level	Answer time
167	Figure	Right	3	5 min
168	Writing	Right	2	4 min
169	Formula	Right	1	3 min
170	Figure	Right	3	5 min
171	Writing	Wrong	2	4 min

Table 2: Learners' data to be saved on the student model to compute the reliability of the assignments

Conclusions and Further Research

In the design of adaptive systems, we must include a multimodal teaching of the knowledge content, incorporating different external representations. This multimodal teaching has attracted attention among the researchers of science education. We are interested in the advantages of the offered possibilities for the use of new technologies to support teachers and learners in a multimodal communication. The posit system incorporates

What is the Dalton's atomic model?		Question ID: 167			
Learners ID	Type of Representations	Type of Answer	Understanding Level of the representation	Answer time	
1005516	Figure	Right	3	5 min	
1013456	Figure	Right	2	4 min	
1014356	Figure	Wrong	3	5 min	
1020345	Figure	Right	2	4 min	
4 learners	Figure	$\frac{3}{4}$ right wrong	$\frac{1}{4}$	2.5 Grade of Difficulty	4.5 min

Table 3: Question data to be saved on the knowledge content model to compute the reliability of the assignments

different external representations to the knowledge content pursuing two aims: First, to provide tools, which attend the diversity, incorporating also different ways of communication. And second, to do research about the challenges and possibilities of the use, controlled and diversified, of the diverse representations of the knowledge content in science education.

The inclusion of the knowledge content model and the student model is very important because by using these models SPEBC will be able to process reliability and validity evaluations. Both the validity and reliability of any test depend ultimately on the characteristics of its items. High reliability and validity can be built into a test in advance through items analysis. Test can be improved through the selection, substitution, or revision of items (Anastasi & Urbina, 1997).

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