ADAPTING ASSESSMENT GOALS TO THE STUDENT'S PROFILE

by
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Abstract. This paper describes a general model for the design of stand-alone intelligent assessing systems. According to this model, a prototype system supporting the assessment of students of age 8-12 who show a low performance in arithmetic word problem solving has been implemented. The main purpose of the underlying research is to study the difficulties the expert part of the computer system faces trying to adapt the teaching goals to the knowledge, strengths, and learning preferences of the individual student, taking under consideration his/her current motivational state.
Keywords: Intelligent Tutoring Systems, on-line assessment, student model, teaching strategy, motivation

INTRODUCTION

Computer-based assessment, assuming sufficient levels of accuracy can be achieved, promises not only faster assessment, but also more consistency and the ability to audit, and statistically analyze all results. An adaptive assessment involves a computer administrated test in which the presentation of each test item and the decision to stop the test are dynamically adapted to the student's performance in the test.

Testing systems commonly use a database of questions to assess the knowledge of students regarding a particular domain: a "test" about a given topic comes as a sequence of questions chosen from the database. Curriculum is essentially a control path through the items of the database and must be explicitly predicted when designing the test. This causes a certain rigidity of the system and leads to a kind of curriculum, which is neither particularly individualized nor adaptable. However, teachers react in a different way in their face-to-face oral examinations using versatile assessing strategies. They even interweave motivational tactics in their domain-based decisions, aiming to built conditions that simulate the wish to participate and learn. According to [Lepper, Aspinwall, Mumme, & Chabay, 1990], expert teachers include among their goals "first, to sustain and enhance their students' motivation and interest in learning, and second, to maintain the pupils' feeling of self-esteem and self-efficacy, even in face of difficult or impossible problems." (p.219). The explicit teaching knowledge implemented in the current generation of Intelligent Educational Systems concerns mostly domain-based aspects of the instructional process, overlooking its motivational aspects.

ASSA (Adaptive System of Student Assessment) is a prototype intelligent educational system based on an adaptive to student's individualities and motivational state assessment model. ASSA model attempts to provide a mechanism for making pedagogical decisions within existing teaching material, which will lead the adaptation of the sequencing of this material to the student's general aptitudes. It has access to a representation of the domain knowledge in the form of a semantic network, which permits the user to use the existing assessing strategy in order to modify its teaching materials by generating different curriculums of instructional activities.

The aim of this paper is to examine the mechanism that supports adaptability in ASSA model, and discuss whether it could contribute to the design of testing systems, which aim at a summative and formative student evaluation. The model has a versatile assessing strategy, which takes advantage of the maintained qualitative overlay student model in order to produce an adaptive curriculum of instructional activities.

The implemented prototype fits with the definition of "one-on-one tutoring systems". A first aim of this prototype is to be able to adapt its performance to the student's knowledge state and mainly to his observed strengths. A second aim of the system is to show motivation-based tactics as defined by Malone & Lepper (1987) and Keller (1983) and become a motivational competent tutor as suggested by Lepper, Woolverton, Mumme, & Gurtner (1993).

KNOWLEDGE REPRESENTATION

The architecture of ASSA is based on a knowledge representation conceptually divided into layers, trying to separate declarative knowledge clearly from procedural knowledge about assessing and motivating but keeping knowledge from different layers highly interrelated.

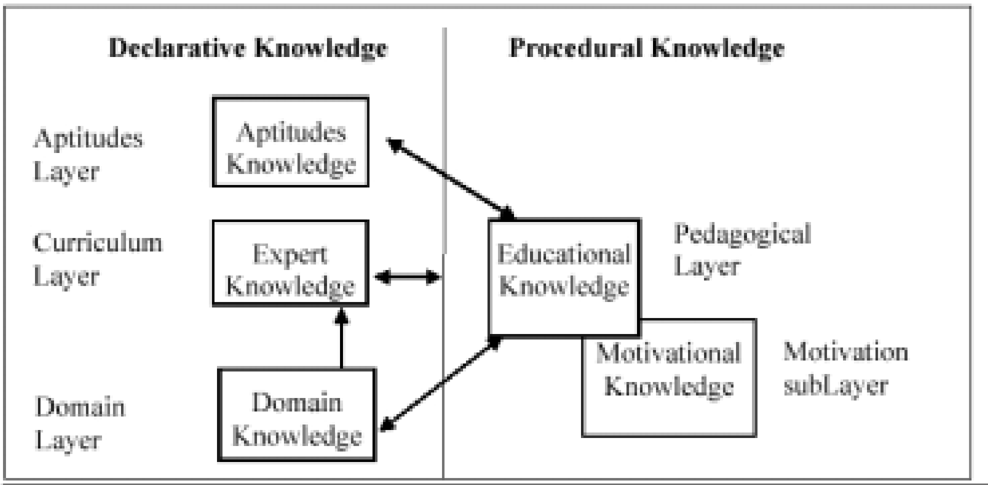

Figure 1. Knowledge Representation in ASSA model

Domain Knowledge

In ASSA declarative domain knowledge is split into small 'chunks' of assessing called "Learning Units" (LU). A Learning Unit is an elementary block of knowledge described with a set of attributes (like type of unit, previous LU to be assessed, next LU to be assessed, whether the current or next LU is obligatory to be assessed etc.). LUs are linked to one another through their semantic associations, consisting in this way a semantic network.. The LUs are represented in the form of frames.

Counters associated to LUs support the system knowledge about the student's performance. The value of these counters reflects the extent to which the student has mastered the LUs. The update operation is done accordingly to the assessment of the student's activity and the diagnosis of his mistakes. These counters specify the domain-based student model. The domain-based modeler is responsible to detect the current state of the student's achievement (domain-based student modeling) and react appropriately. ASSA includes a domain planner for retrieval of domain knowledge during assessing.

Expert Knowledge

The expert knowledge is represented in the 'curriculum' layer. In the curriculum layer, pedagogical goals and subgoals organize the subject matter into successive lessons by pointing down to the domain knowledge layer, using this type of knowledge to guide the floundering student [Lesgold, 1987]. In ASSA, viewing the curriculum layer as distinct from the domain knowledge layer allows the model to include multiple curricular viewpoints on the same knowledge, each of which partitions the subject matter in a different way. This type of organization of the curriculum is useful for both didactics and diagnostic purposes.

As a consequence, the curriculum layer contains knowledge about the conceptual network of the pedagogical objectives to be achieved in the assessing process. This conceptual network, called "curriculum scenario", is expressed as a compound structure that results from the associations of LUs through their existing semantic links. The semantic links can be characterized as 'strict' or 'loose'. A 'loose' link can be changed but a 'strict' one cannot even if the system decides so. The curriculum scenario in effect is stored in a dynamic data list structure called 'current curriculum scenario'. Each time the system decides to make changes to the curriculum in effect, changing the 'loose' semantic links between two or more LUs, a new current curriculum scenario is generated. A 'default curriculum scenario', expressing a proposed by the system assessing strategy, is always available through the interface.

Educational Knowledge

The educational knowledge is used by the assessing strategy planner and is expressed in the form of rules. The assessing strategy planner includes two different planners: the domain planner and the motivation planner. The decisions of the assessing strategy planner are about the selection of the right LU to be presented, the possible extraction of a specific set of LUs from the curriculum, the resequencing of the curriculum, the provision of help etc, according to the student model. To achieve this, the assessing strategy planner consults the domain planner, taking under consideration the existing knowledge about the student’s general aptitudes.

Knowledge about motivation

The motivation sub-layer contains procedural knowledge consisting the motivation planner, responsible to diagnose the current motivational state of the student (motivational based student modelling) and react in order to maintain his/her motivation. In ASSA we have focused on three motivational aspects as proposed by del Soldato et al. (1995), namely effort (or persistence), confidence and independence. To take account of motivational factors, the twin activities of “detecting the state” and “reacting appropriately” are extended by adding a motivational state and motivational planning to the traditional ITS architecture.

Knowledge about general aptitudes

The upper level of knowledge representation contains a single layer called the aptitudes layer. This layer deals with “metacognitive” skills and contains knowledge about the student’s observed through the assessment individual characteristics. Some of these characteristics are learning aptitudes over specific LUs, general aptitudes like general learning strengths or weaknesses etc. The concepts used in this layer are closer to the general terms that teachers often use to evaluate students. Information at the aptitudes layer induce modifications in the way the “current curriculum scenario” is generated.

THE ARCHITECTURE OF ASSA MODEL

ASSA has a typical ITS architecture consisting of four main modules, the student modeller, the assessing strategy planner, the expert module and the interface module.

Student Modelling Module

In ASSA, student modelling is separated into three main parts. The first is based on motivational issues, the second is based on domain-based knowledge issues. A third part is considered based on students’ general aptitudes issues. The three modelling modules have been kept separately for pragmatic reasons. In fact Lepper et al. (1993) make such a separation a “central tenet” for the model they are building of skilled teacher performance. In our system three sets of rules are used to generate the three parts of the student model, the domain-based model the motivational state model and the aptitudes model. These three sets make up the corresponding modellers that form an overlay qualitative student model.

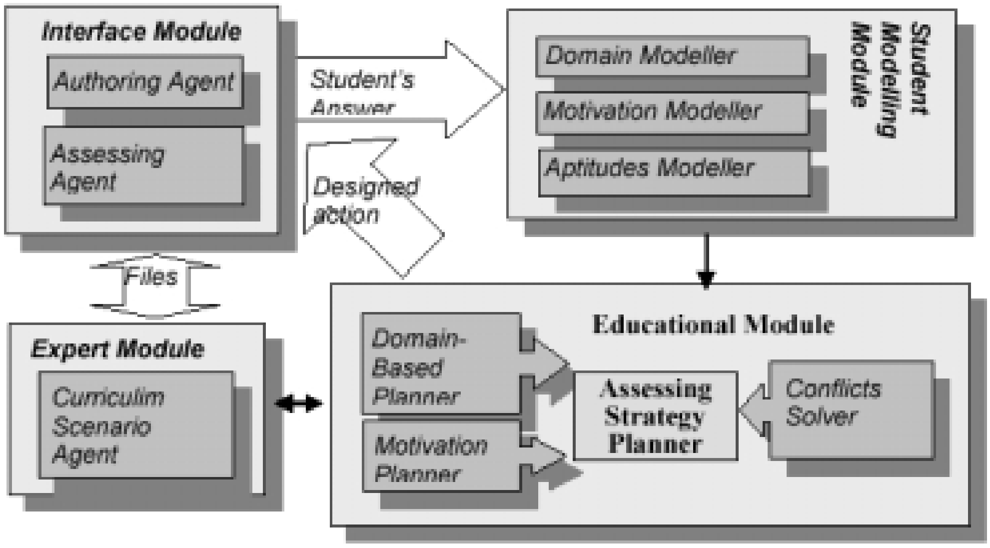

Figure 2. The Model's architecture

The domain modeller analyses the student's performance in order to built a model of what the student knows. The student's answers are analyzed, using diagnostic rules, in order to be classified as right, almost right, almost wrong or wrong.

The motivation modeller focuses on effort (or persistence), confidence and independence. Effort refers to how a task was achieved, confidence relies mostly on the students' beliefs on their efficiency to perform the instructional task [Schunk, 1989], and independence relates to the perceived feeling of needing or not needing the tutor's help to complete the instructional task. Confidence is characterized as low, medium or high incremented and decremented in large or small steps during the interaction according to the motivational sate modeller's rules. Effort is expressed as a function of the student's persistence to answer the presented questions and requests for help to perform the task in question. Effort is measured separately for each LU and complex LU. The asking and offering of help, the rejection of an offered help or the system's interventions offering a detailed hint, affect the student's feeling of independence. Independence is represented as a numerical value with lowest and highest limits, incremental and decremental steps and an independence threshold.

The Aptitudes Modeller has access to the diagnosis table, where the diagnostic process records the systematic mistakes the student makes. The diagnostic table contains also information about the student's giving ups and help requests. From this table the modeller concludes about the student's observed weaknesses and preferences.

Educational Module

ASSA's educational expertise contains knowledge about the assessing strategy in use in the form of productive rules. An assessing strategy is responsible for the selection of the appropriate presentation and assessing methods, and for sending them to the interface administrator, where they become concrete interactions with the student [Sokolnicki, 1991].

The process of assessment can be divided into the following generic stages [Fletcher S., 1992]:

- Define assessment objectives and requirements
- Collect evidence
- Match evidence to objectives and requirements
- Make judgements based on match results

ASSA's architecture contains an assessing strategy planner able of using the existing assessing strategy in order to take decisions about the appropriateness of the next move to be done in the assessment cycle.

The assessing strategy planner is composed of the domain-based planner and the motivation planner. Its main responsibility is to reconcile output from the two first agents of the student model, to solve the conflicts and to decide about:

1. the next type of problem to be presented to the student,
2. the kind of help to be offered, if asked,
3. the changes that have to be made to the current curriculum scenario, according to the student's shown behavior, in order to adapt to his/her observed strengths,
4. the adaptation of the system to the student's detected motivation state.

The domain-based planner is not a typical planner that detects the current state of the learner's knowledge and proposes the appropriate next step, traversing the domain in a progressive manner in the direction of the existing ultimate goal. It takes also under consideration learner's detected weaknesses and preferences. The motivation planner takes into account the student's motivational state and proposes tactics to improve it.

Motivational planning widens the assessing strategy planner's space of possible reactions. However, motivational tactics do not always simply complete the traditional domain-based planning. Sometimes they compete with it as well. In this case conflicts' solver planner, part also of the assessing strategy planner, takes over in order to settle the differences.

Expert Module

All domain expertise in included in the slots of the frames of the domain knowledge.

A curriculum scenario agent is included to the system in order to retrieve the domain knowledge during assessing and to carry out the needed changes in the current curriculum scenario. The adaptability of the system is based on the curriculum scenario agent's ability to change the 'loose' links between the LUs when the assessing strategy planner decides so.

The Interface

The interface is a multi-agent module independent from the rest of the system. It receives orders from the assessing strategy planner and reacts accordingly. Through this interaction the interface offers the teacher the possibility of maintaining the problems' database, the system's parameters and the curriculum scenarios at the start of each session and offers a friendly environment for LUs manipulation.

THE MODEL'S APPLICATION TO A CONCRETE DOMAIN

The ASSA model, methodology and tools have been applied to a domain of teaching of big importance: arithmetic word problem solving. Since the focus is on adaptation of the curriculum rather than this specific application domain, we describe the application only enough to provide background for subsequent discussion.

ASSA prototype system (Georgouli & al., 2000) assesses the student's understanding of a major objective of numeracy in today's word, namely whether she knows which calculation to choose, even if she has to use a calculator, for the whole range of numerical situations which might be encountered in everyday life.

The system asks the student to solve simple problems of addition and subtraction, expressed verbally, keeping the quantities of the problem 'situated' in real world's measures.

In ASSA, we have followed an analysis proposed by Haylock (1991), considered as a relevant analysis to the real needs of the low-attainers. According to this, six different categories of contexts (sets of things, money, length and distance, weight, capacity and liquid volume, time) are used. Additionally, six models have been considered for addition and subtraction (aggregation, augmentation, partitioning, reduction, comparison, inverse of addition) and have been identified thirty-four classes of problems, that relate contexts with models in an appropriate way. Following this analysis, the system is concerned only with assessing the appropriate operation for a calculation which might arise in the chosen contexts.

Furthermore the final types of problems derive from the level of difficulty in syntax each model may have [Malone & Lepper, 1987; Keller, 1983] and from the chosen size of quantities (numbers from 1-20 or 20-100).

Each existing problem in the database belongs to a specific type which plays the role of the LU of the ASSA model.

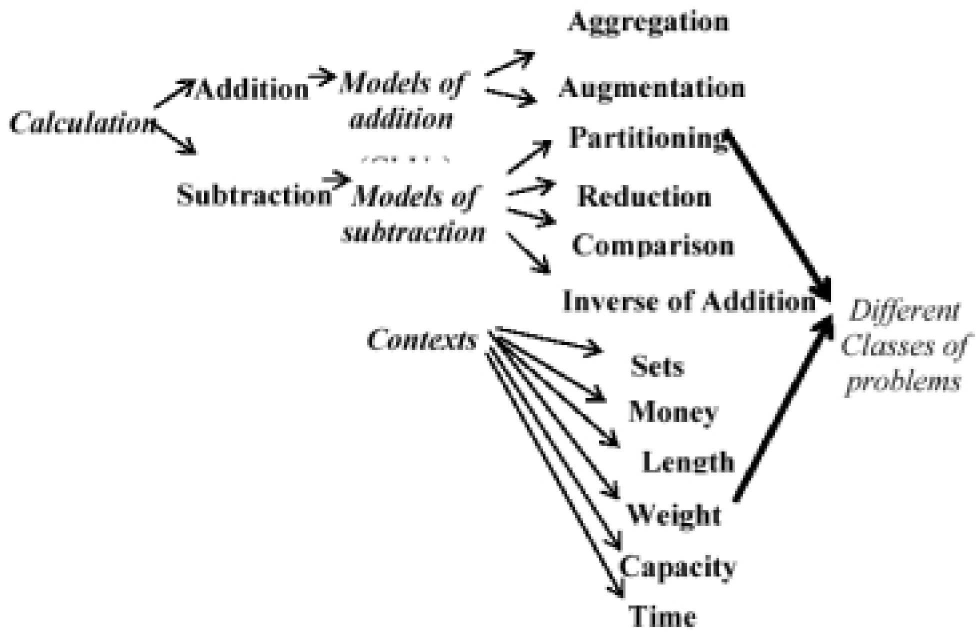

Figure 3: Classes of problems

In ASSA the assessing strategy is responsible for what part of the domain is currently under consideration, which type of problem has to be presenting for solving, the appropriate style and level of difficulty, and how to handle the student's responses. Wrong responses are surely an inevitable part of the learning process and can be an excellent source of information about the student's cognitive strengths and weaknesses [Dockrell, & McShane 1993], information which can guide the system to adapt its assessing strategy to the student's above mentioned characteristic. ASSA's main aim is to track the student's performance, to detect his current motivational state and to change dynamically, if appropriate, the curriculum scenario after each interaction, adapting it to the student's real strengths.

The System's functionality

Within the ASSA model the concept of "curriculum scenario" is of big importance. A complete assessment session can be viewed as the full traversing of the current curriculum scenario. Each type of problem is presented in turn, according to the links among the different types, which compose the current curriculum scenario. The problems are collected from the problems' database and their quantities are randomly generated during the presentation. After the problem is presented, the student can interact giving a right or a wrong answer to the problem, giving up or asking for help. A simulated calculator can always be offered to the student after his/her request or after the assessing strategy planner’s decision. According to the kind of interaction the assessing strategy planner decides what to do next. Its decisions are about to give help or not, to insist in the presentation of problems of the same type, to choose the next type for assessing, to provide hints and finally whether to modify the current curriculum scenario or not.

ASSA’S OUTCOMES AND IDENTIFIED LIMITATIONS

An internal evaluation of the prototype has been employed to explain system’s performance in terms of system’s architecture. Thus, the evaluation process is mostly concerned with performance and knowledge structures of the system, rather than learning improvements. Only those issues, related to the system’s ability to reproduce the appropriate assessment results, have been taken under consideration.

During expert inspections, three teachers of elementary school, five expert teachers in special education and a cognitive scientist have been used as subjects. The evaluation target population was made up of a very limited number of students-three in total- all of whom have used the system under the supervision of their teachers.

During expert inspections, the majority of subjects agreed with the domain analysis and the domain model’s consistency. There were no objections and only some of them made some minor remarks for improvements. All comments and suggestions were noted.

During evaluation the subjects were aware of the adaptive characteristics of the system and seemed attracted by its functionality making a number of interesting remarks. The new acquired expert knowledge was added in the assessing strategy planner’s rules and the system was tested once more. The new behavior of the system satisfied most subjects’ expectations and proved the system architecture to be flexible enough to adapt to the student, as planned.

CONCLUSION/FUTURE WORK

The computer-based assessor described in this paper is designed to emulate a human examiner performing a summative assessment trying to adapt to the student’s profile.

The versatility of the curriculum structure permits the system to adapt itself successfully to the real strengths of the student. This feature is very important, especially when the tutoring concerns students who attain very poorly in the subject area.

In the future we intend to implement the curriculum model into more sophisticated curriculum areas in mathematics and to study the teaching outcomes using a complete version of the ASSA system.

References

[1].del Soldato, T., & du Boulay, B. (1995). "Implementation of Motivational Tactics in Tutoring System." Journal of Artificial Intelligence in Education **6 (4)**: 337-378.
[2].Dockrell, J., & Mc Shane, J. (1993). Children's Learning Difficulties. Oxford, Blackwell.
[3].Fletcher, S. (1992). Competence-based Assessment Technics, Kogan Page.
[4].Georgouli, K., Gregoriadou, M., Samarakou, M.,(1999): "Invidualising the Assessment for Low-Attaining Pupils in Word Problem Solving". Presented at the 9th International Conference on Artificial Intelligence in Education, Le Mans, France, IOS Press.
[5].Haylock, D. (1991). Teaching Mathematics to Low Attainers, Paul Chapman.
[6].Keller, J. M. (1987). "Strategies for stimulating the motivation to learn." Performance and Instruction Journal **26**: 1-7.
[7].Lepper, M. R., Aspinwall, L.G., Mumme, D.L., & Chabay, R.W. (1990). Self-perception and social-perception processes in tutoring: Subtle social control strategies of expert tutors. Self-Inference Processes: The Ontario Symposium. J. M. Olson, & M.P., Zanna, Hillsdate, NJ: Lawrence Erlbaum Associates. **6:** 217-237.
[8].Lepper, M. R., Woolverton, M., Mumme, D., & Gurtner, J. (1993). Motivational techniques of expert human tutors: Lessons for the design of computer-based tutors. Computers as cognitive tools. S. P. Lajoie, & S.J., Derry, Hillsdate, NJ: Erlbaum Associates**:** 75-105.
[9].Lesgold, A. M. (1987). Toward a theory of curriculum for use in designing intelligent instructional systems. Learning Issues for Intelligent Tutoring Systems. H. Mandli, & A.M., Lesgold. New York, Springer Verlag.
[10].Malone, T., & Lepper, M. R. (1987). Making Learning Fun. Aptitude, Learning and Instruction: Cognitive and affective Process Analyses. R. Snow, & Faee, M., Hillsdate, NJ: Lawrence Erlbaum Associates**:** 223-253.
[11].Sokolnicki, T. (1991). "Towards knowledge-based tutors: a survey and appraisal of Intelligent Tutoring Systems." The knowledge Engineering Review **6(2)**: 59-95.

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