Supporting Web-based Learning through Adaptive Assessment

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Abstract:

Web-based assessments can be used in different phases of education in order to support students and make learning easier and more effective for them. This support can range from the assessment of readiness for a particular educational institution, over methods which improve the learning process itself such as peer assessment, to the assessment of the progress and knowledge level by the use of performance self-assessments. For these assessments, typically tools and methods are provided, which treat all learners in the same way and adapt only a little or, in the most cases, not at all to the individual needs and characteristics of learners. In this paper, we show the potential of adaptive web-based assessment in different learning applications. Adaptive web-based assessment aims at accommodating the individual needs and characteristics of students. We introduce adaptive systems in the area of readiness self-assessment, performance self-assessment, and peer assessment. Discussion is provided on the architecture of these adaptive systems and how these systems incorporate individual differences.

Keywords: adaptive assessment, readiness self-assessment, performance self-assessment, peer assessment

1. Introduction

Web-based assessment is widely used to support students in learning and helps them to achieve their learning goals. Assessments can be used in different contexts and at different stages of the learning process. For example, readiness self-assessments are often used in open universities to help students to determine if they have the necessary skills and attitudes for the successful completion of a course or program. Another application of web-based assessment includes performance assessment where the knowledge level and the learning progress of students is assessed. To provide students with the possibility to check their acquired knowledge and to get feedback about their learning progress, self-assessment tests are commonly used in technology-enhanced learning environments, especially in learning management systems. Another pedagogical strategy in web-based learning includes peer assessment where students are asked to assess peers' assignments. Such web-based assessments can be used in distance education systems where it is impractical to assume that students can gather simultaneously in a common space.

As Brusilovsky (2001) argued, learners have different needs and these differences should also be considered in web-based education. In web-based assessment, this can be achieved in different ways. In this paper, we present three novel approaches from different domains, which show how adaptive web-based assessment can support learners.

The first approach deals with adaptive readiness self-assessment. Adaptivity is provided with respect to the counselling process, which is tailored to the individual requirements and needs of users. The questionnaire is dynamically generated, based on information about the users in terms of their previous answers. Therefore, users have to answer only questions which are relevant for them, and can be assessed more precisely because the questions fit the individual students. As a result, the counselling process is more precise and efficient, and the users get better feedback. In the second approach, the use of performance self-assessment tests in learning management systems is accommodated to the students' learning styles. Adaptivity affects the position and number of self-assessment tests in online courses. This leads to a learning environment where students can benefit more from self-assessments since they are adapted to their individual learning preferences. Moreover, self-assessment tests can also be used to gather information about the students' learning styles. This additional information can then be used to provide more suitable adaptivity. The third approach deals with peer assessment and the influence of the assessors' learning styles on the ratings they give their peers. Based on the assessors' learning styles, their ratings are weighted differently with respect to specific assessment issues. Thus, students can obtain more accurate and better feedback, resulting in better quality of assessment and time efficiencies for both students and assessors.

In the following sections, the three approaches for adaptive assessment are introduced. Discussion is provided about the architecture of the systems, as well as about how they support students by the use of adaptive assessment.

2. Readiness self-assessment

Online readiness self-assessments are widely used in universities that provide open and distant education service. The purpose is to help potential students to identify the learning style and requirement of studying as a distant learning student, and to decide if the distant learning format is the right choice for them. Most current readiness self-assessment tools are online questionnaires. By completing the questionnaires, potential students read some information and get a final score related to their answers to the questions on the questionnaires. The high score means high degree of their readiness. This kind of model is relatively simpler and need to be upgraded in several aspects. Actually, in this paper, we regard readiness self-assessment as a kind of counselling process between our self-assessment system and its users. To do so, we can analyse the real counselling process to understand what should be done to upgrade the current model. The self-assessment system is functionally like a counsellor, who needs to know the background information of his/her client (the user of the system) and ask necessary questions to get more required information of the client until the counsellor finally form an assessment about the client. Also, during the counselling process, the counsellor may also PICK and/or SKIP some questions of all possible or potential questions according to the needs to logically understand the client by his/her answers to previous questions, and form a more and more specific figure of the client and finally the assessment to the client about his/her readiness.

As most of current systems adopted in other universities, the previous system of Am I Ready for Athabasca University is a self-assessment questionnaire: Am I ready for Athabasca University? It involved several self-test groups, including Goals, Preparation, Supports and Commitment, which are content-fixed or static (i.e., tests that do not adapt to the user's responses). Each of these groups is a Web-based questionnaire. The user can choose one of several options (Yes or No) for each question and finally get a score. The score reflects the total number of Yes and No answers, but is relatively correlated with the measure of readiness for distance education. The shortcoming of the current tool is that it does not help the prospective students very much to find out what are needed to succeed and how to meet those needs. Also, all users get the same questions regardless of their background and other information, i.e. it can not dynamically alter the set and sequence of questions according to the user's answers in order to more precisely assess the student's readiness.

The new version of AM I READY for Athabasca University, in contrast, is an adaptive online self-assessment tool for prospective students of Athabasca University. It is based on knowledge models of the counselling process. It involves better understanding of a user and creates an effective self-assessment process with a smaller question set than the previous self-assessment system

2.1. Related work

Adaptive questionnaires and self-assessments have been the subject of considerable research, much of which focuses on development and maintenance of an effective student model. An adaptive web-based questionnaire for course survey is developed and evaluated by Chou et al. (2000). They use the answers to some key questions, which are called Adaptive Questions, to determine the next series of questions and to skip unrelated questions. Only few questions are Adaptive Questions in their question set. Unlike the other questions, they only show one by one on individual Web page for the convenience to immediately decide and lead to other related question groups in the following page. This restriction is not existed in our AM I READY system, in which all kinds of questions are combined together and priorities are used to order or control the proper presentation of following related questions. Nokelainen et al. (2001) designed an adaptive questionnaire based on Bayesian Modelling. Bayesian statistical techniques are used to create an individual learner's profile (in Profile Creation Phase) and optimize the number of questions presented to each user (in Query Phase). It is very suitable for such surveys or test applications that we only know few about their results and categories. But it is not fit for more self-assessment system such as AM I READY project, where all possible relations between questions can be coded and put to the knowledge base, because it needs a more controllable and user specific self-assessment process. More recent works on knowledge modeling have focused on a visual formalism and an evaluation tool, XDM, context-sensitive dialogue modelling, to model user-adapted interface based on extended Petri nets (de Rosis et al., 1998). Furthermore, research work deals with adaptive testing (Jettmar and Nass, 2002), in which testing is adapted interactively to match the ability level of the examinee by means of a statistical method called "Item Response Theory".

2.2. Knowledge modeling

Let's have a look at a real counselling process again. There are two roles involved: a counsellor, who is the expert of the specific counselling field and the controller of the current counselling process, and a client, who has his/her own needs and background information, which is needed to know to the counsellor during (and maybe

before) the counselling process. The more information the counsellor knows about the client, the fewer questions he needs to ask while trying to understand the client and then give an assessment to him/her. Respectively, there are several models built to support the adaptive self-assessment of AM I READY, namely, User Model, Counselling Model, Process Model and Assessment Model. User Model is the knowledge about the client, including static (produced before or at the beginning of the counselling process) and dynamic ones (produced during the process). We model the counsellor by Counselling Model (related to field knowledge), Process Model (knowledge about the counselling process), and Assessment Model (knowledge about the assessment). All these models are showed in Figure 1.

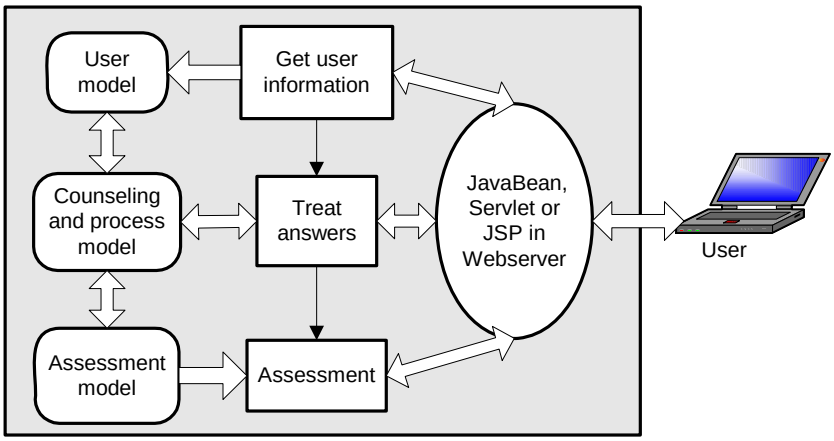

Figure 1. Knowledge Models and Architecture

User model: There is lots of information about a user. However, we only need those that mostly affect the readiness self-assessment of the user. We use a *static user model*, which is gathered at the beginning of the self-assessment, as depicted in Figure 2, and a *dynamic user model*, which responds to the user's choices during the assessment and is always changing during the assessment.

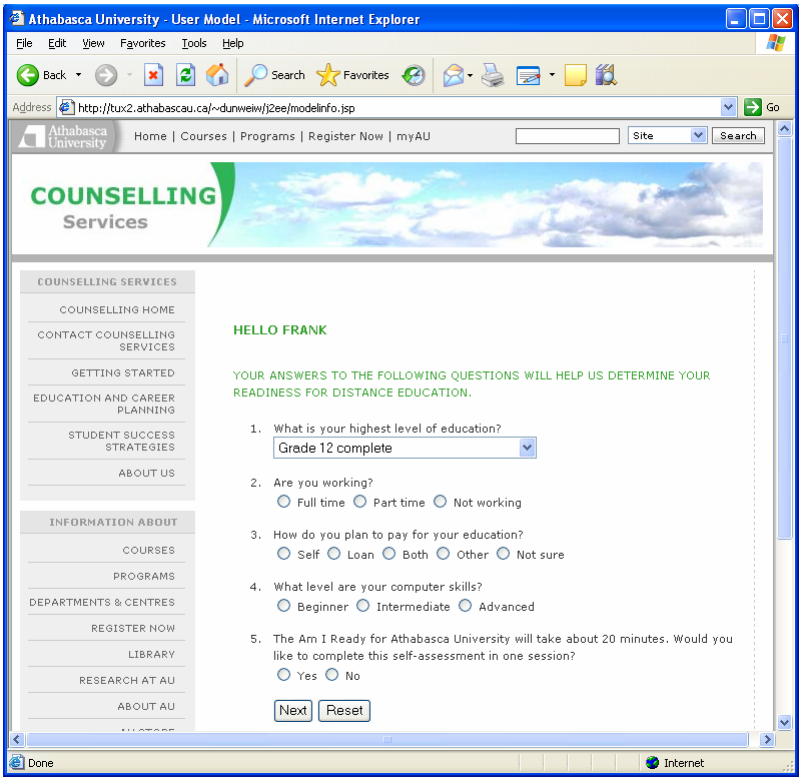

Figure 2. Static user model Web page

Figure 2 shows the Web page for building the user model. Users can make their choices at the very beginning of their self-assessment by clicking the options of these parameters. The values of those model

parameters directly affect the questions the system is going to ask later. For example, if a user told the system that he/she has graduated from college or above, the system is not going to ask any questions to assess his/her readiness of basic writing skills. Two kinds of relations have been built into the model about what *questions* or *fields* are "Disabled", "Enabled" or "Plus" priority by a specific value of a parameter. This is the *static* user model – they are not going to change during the assessment after they have been set. The inner representations are the parameters and their relations in the form of *Facts* and *Rules*.

The *dynamic* user model is essentially about the records of the user's choice history along the assessment, which is always changing during the assessment. The main items include the answer of each question, records of questions that are "Disabled", "Enabled", and those that have high priority ("Plus"). The increasing records will be continuing affect the questions of the next page asked to users according to the same rules as mentioned above.

Counselling model, process model and assessment model: Needless to say, counselling knowledge is always different in contents, forms and styles according to different domains and processes. However, we can still try to model the general level of the counselling knowledge, like the methods of counselling knowledge representation and resolution. We have captured five kinds of knowledge for AM I READY, which forms the Counselling Model (Questions, Relations, and Instant Information), Process Model (Process), and Assessment Model (Assessment).

Questions are the knowledge sets about all questions of a system, its fields and sub-fields, and predefined answer types. All questions are divided into eight groups (or fields) in AM I READY, e.g. Educational & Career, Financial Readiness, Academic Preparation, Course/Program Awareness, Commitment & Motivation, Computer Readiness and so on. Each field has some sub-fields. Like that Financial Readiness includes four sub-fields, namely, General Information, Family Support, Loans and Awards. Each question belongs to a sub-field and each sub-field belongs to a field, which forms a standard hierarchical tree structure. All questions are in plain text and can have predefined different kinds of answers. Currently, AM I READY has (1) Yes and No, (2) Yes, No and Not Clear, (3) Grade and (4) Multi-Checks. The last one can have multi-choices answers. Questions and related answer options can be seen in Figure 3. Users can choose their answers to those question by click related radio buttons. Even questions of Multi-Checks type can be represented by multi radio button pairs.

Instant information is the additional information related to answers of certain questions. A user can see the instant information immediately after he/she clicks an answer button, as showed in Figure 3. The main purpose of instant information is to give users immediate response, and provide related resources (links or emails) and guidance to follow the self-assessment process.

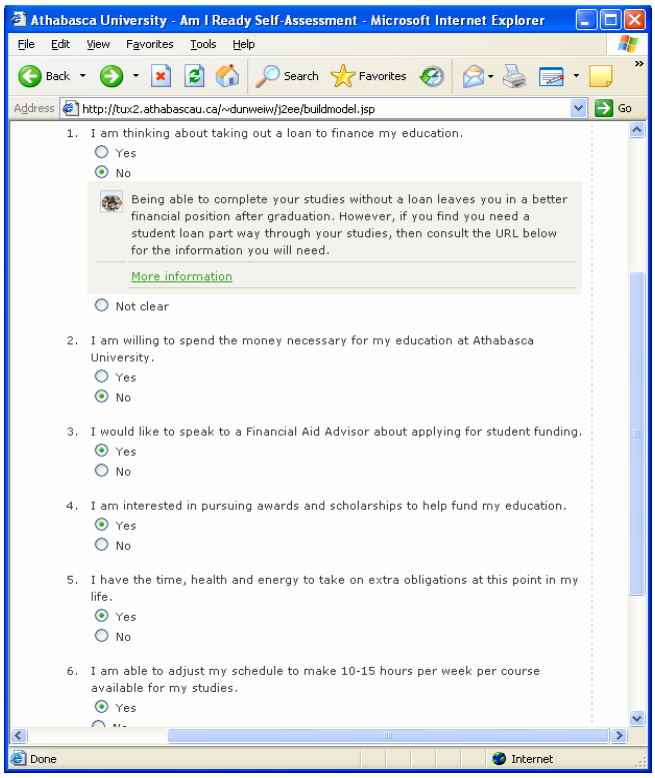

Figure 3. A self-assessment Web page

Relations include all relations between questions. We also regard them as rules. In AM I READY, relations can be question to question(s), question to sub-field(s), and the latter can finally become question to all questions belonging to the sub-field(s). So the relations are always one-many relations. There are four types of relations, which are *Enable*, *Disable*, *Plus*, and *Contradictory*. The first three relations are in this form:

(*Enable* (*Answer*(*i*) *of question*(*j*), (*question list*), (sub-field list))) (1)
(*Disable* (*Answer*(*i*) *of question*(*j*), (*question list*), (sub-field list))) (2)
(*Plus* (*Answer*(*i*) *of question*(*j*), (*question list*), (sub-field list))) (3)

Enable means that an answer of a question will enable some questions or other questions belonging to some sub-fields if they have been disabled before. *Disable* relation can disable some questions that are no longer needed to ask the user according to the user's current answer. *Plus* means to enable some questions and add the priority of those questions, which can cause those questions to be asked earlier. *Contradictory* means that an answer, say, *Answer*(*i*) *of question*(*j*) in (2), are contradictory to some other answers, say, *list of answers of some questions* in (2):

(*Contradict* (*Answer*(*i*) *of question*(*j*), (*list of answers of some questions*))) (4)

Process is the knowledge of how to control the counselling process. To improve the effectiveness of a self-assessment, modelling the counselling process in a suitable way is very helpful. And it is also useful for AM I READY system to understand the process and make suitable or nature "dialog" between users and the system. Just as a real counsellor is going to do, there are two critical methods: (1) *Adopting models* mentioned above, including user model and counselling model, (2) *Changing Priority* in real time and *Sort Questions* by their priority. By adopting user model and counselling model, AM I READY can FILTER, SKIP and GATHER questions, and by the help of priority handling, AM I READY can ask more related questions at the same time creating a more natural flow and facilitating more user friendly interaction. For example, after the user was choosing "Yes" or "Not Clear" to the first financial question: "*I am thinking about taking out a loan to finance my education.*", all detailed questions about the loan are going to show on the next Web page (see Figure 4). Not like proposed by Chou et al. (2000), in AM I READY, every question can be an "Adaptive Question" and questions on the next Web page are always most related to current answers. It gives the system great flexibility and produces a kind of flexible or dynamic "Webpage-Dialog". With the flexible filtering and skipping functions, AM I READY is more effective and suitable for applications with large set of question. On the other hand, by the help of these mechanisms, we can be less serious about the question set, while we compensate the feature by capturing and building the relations of those questions.

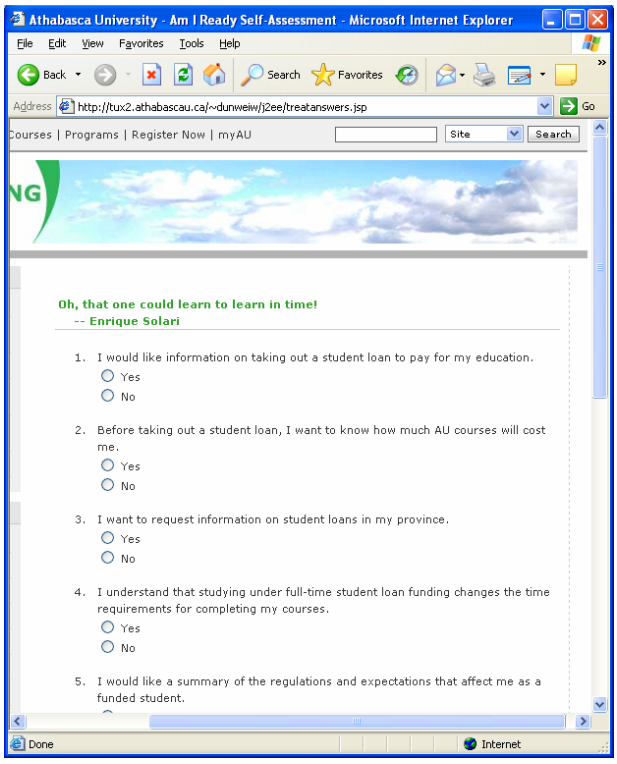

Figure 4. A dialogic Web page after Figure 3.

Assessment is a recommendation which is displayed at the conclusion of the self-assessment. We do not use a single score to assess the readiness of a user. Instead, we supply some assessment information plus remedial suggestions which help potential students to understand their current readiness and steps to take to enhance their probability of success. We have designed two kinds of assessment information: *Question Related* and *Question Group Related*. The latter has more than one condition coming from different fields and questions:

$$\textbf{(Assessment (i)} \leftarrow \textit{(answer(i) of question(j), ……))} \tag{5}$$

Users can browse, download, email, and print the final assessment information in AM I READY system.

Structure and implementation for reasoning and interaction: As mentioned above, AM I READY is a knowledge intensive system. We have modelled different knowledge with different representation. We can then use different expert or reasoning tools and methods to realize the self-assessment process. For being compatible with current information infrastructure of learning environment of Athabasca University, we have put the knowledge, including rules, relations, facts and text information, into PostgreSQL database, and the system reasons by SQL statements. The system structure is depicted in Figure 5, and the overall counselling or self-assessment process is depicted in Figure 6.

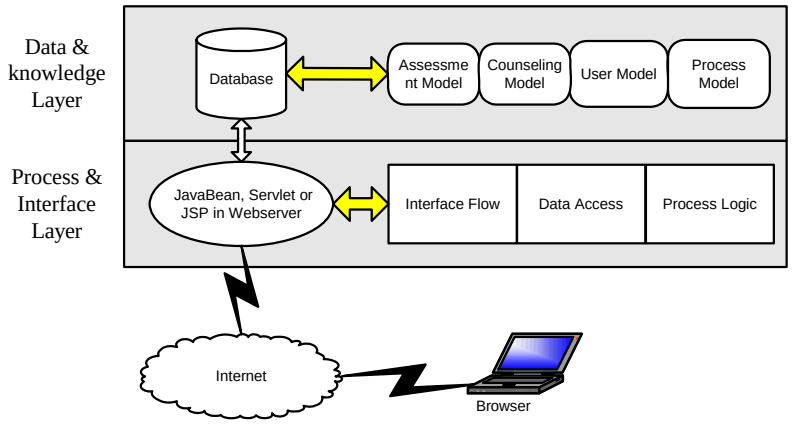

Figure 5. System structure

The system can be functionally divided into two layers: Data & Knowledge Layer, and Process & Interface Layer. All the data and knowledge are stored in the first layer with the help of database and SQL reasoning, while Java/JSP on the second layer handles the interface and interaction between the system and users. Users can online access the system by the Internet.

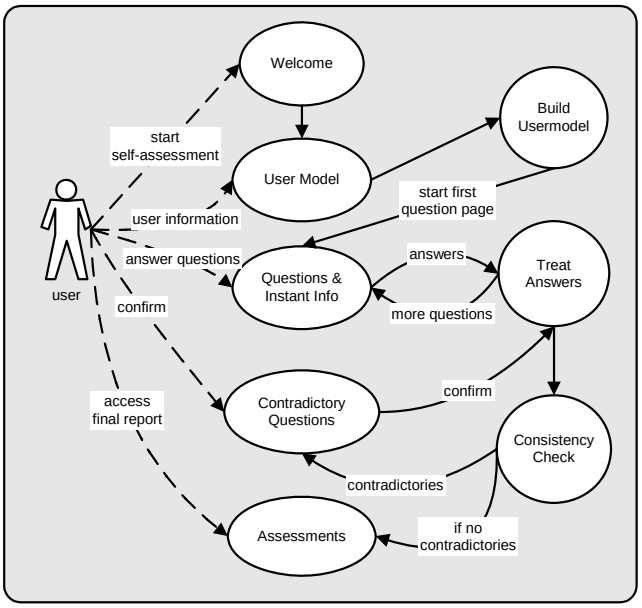

Figure 6. Interaction and processing among components

As can be seen in Figure 6, a user can input user information at the beginning of the self-assessment. The system then builds the user model according to the inputted information. Based on the first filtered or arranged question set, the system starts to ask questions and the user starts to answer those questions in turn. After it accepts the user's answers and selects the next set of questions by reasoning and sorting all currently available questions, the system then asks the most needed and relevant questions to the user. The process is always adaptive to follow the direction of "modelling", "understanding" and "assessing" the user. If there are no more questions to ask, the system is going to check answers to see if there are some contradictories among them by the contradictory rules in (4). If yes, related questions will be sent back to the user for double check. After the contradiction has successfully been resolved, the final assessment information will be displayed on the last page.

3. Performance self-assessment

Performance self-assessment can play an important role for providing adaptivity. On one hand, the use of self-assessments in a course can be adapted in order to accommodate students' needs. On the other hand, self-assessments can help to get information about the students which can be used to improve the student model and therefore enables the system to provide more suitable adaptivity.

Learners have different needs and characteristics. They differ, for example, in their learning goals, their knowledge about the domain, their cognitive abilities, and their learning styles. These individual differences affect the learning process and are the reasons why some learners find it easy to learn in a particular course whereas others find the same course difficult (Jonassen and Grabowski, 1993).

This section focuses on adaptivity based on learning styles. Considering learning styles in the learning process has potential to make learning easier, leading to better learner achievement. On the other hand, learners with a strong preference for a specific learning style might have difficulties in learning if their learning style is not supported by the teaching environment (Felder and Silverman, 1988; Felder and Soloman, 1997).

In this section, we describe a novel approach to provide adaptivity based on learning styles in learning management systems (LMS) and point out the role of performance self-assessments in the adaptation process. Learning management systems such as WebCT (2007), Blackboard (2007), and Moodle (2007) are commonly and successfully used in e-learning. They provide a variety of features to support teachers and course developers to create and manage their online courses. Courses can include different kinds of learning objects such as learning material, self-assessments, forums, chats, assignments and so on. However, at current stage, a typical LMS provides for each learner the same course rather than incorporating the different needs of students.

The process for providing adaptive courses consists of two steps: firstly, the needs of the students have to be detected and secondly, the courses have to be adapted based on the identified needs. Self-assessment tests in form of theoretical questions as well as practical exercises can play a central role in both steps of the adaptation process. Both kinds of tests help the students in learning, give them feedback on their knowledge, and show them their progress in the course. However, with respect to learning styles, students have different preferences regarding self-assessment tests. In the proposed concept, adaptivity is provided in terms of the order of the tests in the course as well as the number of recommended tests. Moreover, based on the behaviour and performance of students regarding the self-assessment tests, additional information about the students can be gathered to improve the student model.

After the description of related work and background information, we introduce a concept for enhancing LMS with adaptivity based on the Felder-Silverman learning style model (FSLSM) (Felder and Silverman, 1988). We used the open source LMS Moodle (2007) as a prototype and developed an add-on that enables Moodle to automatically provide adaptive courses that fit to the learning styles of the students. Providing adaptivity related to performance self-assessment is a core element in this extension and is described in detail. Furthermore, we show how performance self-assessment can be used to gather information about the students' learning styles.

3.1. Related work and background

A lot of research has been done dealing with investigating and developing adaptive systems (Brusilovsky, 1996; Sadat and Ghorbani, 2004). Adaptive systems aim at providing courses that fit to the individual needs of learners. Adaptation features can be classified regarding their aim into two groups, namely adaptive presentation and adaptive navigation support (Brusilovsky, 2001). Adaptive presentation includes adaptation features based on content such as adaptive multimedia presentation, adaptive text presentation, and adaptation of modality. Regarding adaptive text presentation, it can be further distinguished between natural language adaptation and canned text adaptation, which again includes inserting/removing of fragments, altering fragments, stretchtext, sorting fragments, and dimming fragments. On the other hand, adaptive navigation is based on links and includes features such as direct guidance, map adaptation, as well as adaptive sorting, hiding, annotating and generating of links.

A number of adaptive systems exist, which focus on providing courses that fit to the learning styles of the students. Examples of such systems include CS383 (Carver et al., 1999), IDEAL (Shang et al., 2001), MAS-PLANG (Peña et al., 2002), iWeaver (Wolf, 2003), TANGOW (Paredes and Rodríguez 2004), and AHA! (Stash et al., 2006). iWeaver, for example, provides students, who prefer an impulsive learning style regarding the Dunn & Dunn learning style model (Dunn and Dunn, 1974; Dunn and Griggs, 2003), with the option of self-assessment by providing them with access to a Java compiler. Adaptive link ordering as well as adaptive link hiding is used in this case.

While supporting adaptivity is a big advantage of these systems, they also have severe limitations. For example, adaptive systems lack integration, supporting only few functions of web-enhanced education, and the content of courses is not available for reuse (Brusilovsky, 2004). On the other hand, learning management systems provide a lot of simple features to administer and create courses. As such, they have become very successful in e-education, but they provide very little or, in most cases, no adaptivity (Graf and List, 2005).

3.2. Providing adaptivity in learning management systems

In this subsection, we propose a concept for providing adaptivity regarding learning styles in learning management systems. First, we introduce the learning style model on which our concept is based. Subsequently, we describe how we extended Moodle by an add-on which enables the LMS to provide adaptive courses based on the learning style of the students.

3.2.1. Felder-Silverman learning style model

Several different learning style models exist in the literature, each proposing different descriptions and classifications of learning types, for example, the model by Kolb (1984), Honey and Mumford (1982), and Felder and Silverman (1988). Looking at adaptive educational systems which incorporate learning styles, Felder-Silverman learning style model (FSLSM) is one of the most often used model in recent times and some researchers even argue that FSLSM is the most appropriate model for the use in adaptive web-based educational systems (Carver et al., 1999; Kuljis and Liu, 2005).

The Felder-Silverman learning style model characterizes each learner according to four dimensions: *active* learners learn by trying things out and working with others, whereas *reflective* learners learn by thinking things through and working alone. *Sensing* learners like to learn concrete material and tend to be practical, whereas *intuitive* learners prefer to learn abstract material such as theories and their meanings and tend to be more innovative than sensing learners. *Visual* learners remember best what they have seen, whereas *verbal* learners get more out of words, regardless whether they are spoken or written. *Sequential* learners learn in linear steps and prefer to follow linear stepwise paths, whereas *global* learners learn in large leaps and are characterized as holistic.

3.2.3. Architecture of the add-on for Moodle

Moodle was chosen for our experiment based on a preceding evaluation of open source LMS (Graf and List, 2005). According to this evaluation, Moodle achieved the best results regarding the overall functionality as well as the adaptation issues and therefore was considered as the most suitable LMS for extending to an adaptive one.

We developed an add-on to Moodle that allows the LMS to provide courses which are adapted to the learning styles of the students. Figure 7 shows the implemented extensions in the architecture of the LMS. The first extension deals with detecting and storing the learning styles of the students. For detecting learning styles, we used the Index of Learning Styles (ILS), a 44-item questionnaire developed by Felder and Soloman (1997). We added the ILS questionnaire to the registration form in Moodle, which enables us to calculate the resulting learning style preferences from the students' answers, and stored the preferences in the student model. The second extension aims at the expert model, which is responsible for storing all available learning objects. As an extension, we added a field in the authoring interface which provides the authors with the option to specify the learning objects by some additional meta-data which are required for generating adaptive courses. The third extension enables the system to automatically provide courses that fit to the learning styles of the students. Therefore, the adaptation module was developed, which is responsible for (1) accessing the information about students' learning styles through the student model, (2) calculating how a course should be composed in order to fit the students' learning styles, (3) accessing the suitable learning objects from the expert model, and (4) presenting them to the students via the interface module in the LMS.

The possibility to compose a course for students with different preferences is based on adaptive features, which specify how a course can change for students with different preferences. At current stage, adaptation features concern the sequence and number of specific types of learning objects (e.g., self-assessment tests, examples, and so on). The implemented adaptation features include the position of outlines, conclusions,

examples, exercises (practical self-assessment tests), and theoretical self-assessment tests as well as the number of examples and exercises. However, the concept can also be extended by adaptation features referring to other types of learning objects or other adaptation techniques. In the following subsection, adaptation features regarding performance self-assessment (practical and theoretical self-assessment tests) are introduced.

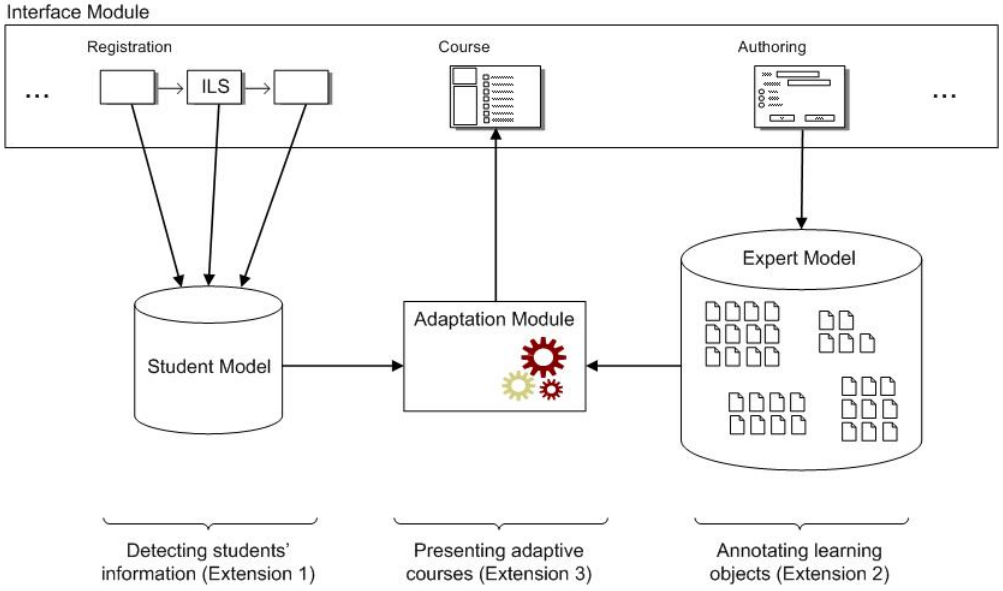

Figure 7. Extensions of the LMS architecture

3.3. Adaptive features for self-assessment

Each learner has a different way of learning and therefore the preference for and the use of self-assessment is different. We include two different kinds of self-assessment tests. For testing the acquired knowledge, the course contains theoretical self-assessment tests. The results of these tests are available for the learners after submitting the answers. The questions contained in such a test can be about facts or concepts, refer to an overview or to details, be based on particular multimedia types such as images and text, or deal with interpreting or developing solutions. Each question is related to the learning object(s) it is about. Thus, learners can be easily guided to explanations if they need hints. The second type of self-assessment tests are exercises which provide learners with opportunities to practice. Again, students receive feedback straight after they have done the exercises. Tasks can be about interpreting predefined solutions or developing new solutions.

The theoretical self-assessment tests can be adapted in terms of their position in the course. They can be presented at the beginning of each chapter, at the end of each chapter and/or at the end of the course. Intuitive learners like challenges, whereas sensing learners prefer to solve problems/tasks by standard approaches they have learned before. Therefore, sensing learners get presented tests at the end of each chapter, whereas for intuitive learners, such tests are presented at the beginning of each chapter. Since active learners like to try things out and work actively, we present tests at the beginning and at the end of each chapter. In contrast, for reflective learners, we present tests only after the learning material in order to give reflective learners the possibility to learn the material first, reflect on it and then perform theoretical self-assessment tests about it. While sequential learners are good in using partial knowledge, global learners have difficulties with it. Therefore, the presentation of theoretical self-assessment tests should be avoided at the beginning of a chapter for global learners but can be provided for sequential learners. Because the learning progress of sequential learners is linear, they prefer to be tested in shorter intervals than global learners who need more time to get the big picture of a topic. For the former, tests should be provided at the end of each chapter while for the latter tests can also be presented at the end of a course.

In order to fit the needs of learners with respect to exercises, we adapted the number of exercises and the position, distinguishing between presenting exercises at the beginning of each chapter and/or at the end of each chapter. For sensing learners, the number of exercises is high since they tend to like practical problem solving, whereas for intuitive learners the number of exercises decreases because they do not like repetition. As for the theoretical tests, exercises are presented at the beginning of each chapter for intuitive learners and at the end of each chapter for sensing learners. For active learners, it does not matter where exercises are presented, but they prefer to solve many of them. In contrast, reflective learners focus more on the learning material and therefore we decrease the number of exercises and present them at the end of each chapter. For sequential and global

learners, we do not adapt the number of exercises but we avoid to present exercises at the beginning of the chapter for global learners since for them it is important to get the big picture of the topic first before solving tasks.

3.4. Self-assessment for improving adaptivity

Providing adaptivity requires knowing the needs of learners. In the proposed add-on, this is done by a collaborative student modelling approach where the students are explicitly asked to provide information in terms of filling out the ILS questionnaire. The majority of adaptive systems are using the same approach. However, it is argued that questionnaires have to deal with the problem that the given answers might not correspond to the real behaviour the questions aim to investigate, both intentionally and unintentionally (Draper, 1996; Paredes and Rodríguez, 2004). Therefore, recent research is done on an automatic student modelling approach (Cha et al., 2006; García et al., in press). In this appraoch, the students' actions and behaviour in the course are used to automatically infer their learning styles.

Self-assessment tests act as a good source to get information about learners such as their knowledge about a topic and their learning styles. With respect to our framework, several patterns can be considered to gather information about the learning styles of the students based on self-assessment tests. Therefore, self-assessment tests are not only used to be adapted to the students' learning styles but they can also help to collect data for building a more accurate student model and therefore improve adaptivity.

The following patterns can be considered. Sensing learners favour concrete material like facts and data whereas intuitive learners prefer to learn abstract material such as theories and their underlying meaning. Analysing the performance of questions about theories/concepts and facts gives us therefore an indication of the preferred learning style. Another characteristic of sensing learners is that they like to check their already acquired knowledge by theoretical self-assessment tests. Therefore, the number of performed tests is a further pattern. Furthermore, sensing learners tend to be more patient with details and work carefully but slowly. Because they tend to check their answers carefully before submitting a theoretical self-assessment test, another pattern is the number of revisions performed before handing in a test. Also the time taken for such a test is considered as pattern. Because intuitive learners welcome challenges, they benefit more from exercises. Therefore, the number of visits and the time spent on exercises serves as another pattern. For active learners, who have a preference for testing and experimenting, we also consider the use of exercises, incorporating the number of visits and the time a learner deals with exercises. For visual and verbal learners, the preference for multimedia elements can be considered. For example, learners who perform well on questions about graphics can be considered as visual learners whereas learners who perform well on questions about content from audio material can be considered as verbal learners. Sequential learners are more comfortable with details, whereas global learners tend to be good in seeing the "big picture" and connections to other fields. Therefore, the performance of answered questions dealing with overviews of concepts or connections between concepts and questions about details serves as a pattern for this dimension. Another pattern deals with the overall performance of theoretical self-assessment tests. According to Felder and Silverman, sequential learners perform in general better in tests than global learners.

4. Peer assessment

Peer assessment is an interactive assessment method that enhances student interpretation and reflection and enables instructors to improve their understanding of student performance. Students are capable of learning how to critique peer work and accept peer criticism, thereby developing their critical thinking skills and self-reinforcement through peer assessment (Liu et al., 2002).

Peer assessment is one form of group assessment, which can include student involvement not only in the final judgment made of student work, but also in the prior setting of criteria and the selection of evidence of achievement. However, the issue of fairness has to be concerned in group assessment. For example, the awarding of ratings may not accurately reflect the individual student's achievement due to subjective judgment, bias or insufficient assessment ability.

In this section, we propose a methodology that aim at reducing the subjective judgment by aggregating students' ratings and considering the individual learning styles of students who give ratings in the assessment process. Based on this methodology, we developed a system for adaptive peer assessment. The aggregated assessment considering students' learning styles may enhance the accuracy of the assessment and provide students a better feedback.

4.1. Related work

Peer assessment is a widely adopted technique that can be applied to improve learning processes (Strachan and Wilcox, 1996). Web-based environments typically enable students to develop their individual learning portfolios and conveniently assess those of their peers. A web-based peer assessment system successfully assists students in developing their understanding. As demonstrated by Liu (2003), students' achievement increased significantly as a result of the peer assessment process and the number of students willing to take part in learning activities also significantly increased.

However, a major concern in peer assessment is the fairness of the ratings when students are rating other students. Some research is done on peers' bias in evaluating other peers. For example, May and Gueldenzoph (2006) studied the effect of social styles (assertiveness and responsiveness) on inter-group peer evaluation on project team members. They found out that students gave high ratings to those with the same social style and low ratings to those with opposite social style. However, in our proposed methodology, peer assessment is done anonymously which means that students do not know who owns the work they are assessing rather than evaluating the work of a specific person. Therefore, disparity in ratings can only occur from students' individual characteristics and abilities of doing the assessment. An example of studies that focus on individual differences of assessors is the study by Sherrard and Raafat (1994). In their study, women gave significantly better ratings than men. However, it has to be considered that women on average also had a higher GPA in this sample. Another study deals with influences on performance appraisal systems and investigates the relationship between perception of one's organization, the beliefs about appraisal systems, raters' orientation to appraisal systems, and the specific rating behaviour (Tziner et al., 2001). Focusing on the role of personality, Tziner et al. (2002) found support for the hypothesis that raters who are high on conscientiousness were more likely to discriminate among ratees and were less likely to give ratings that reflect their general attitudes towards performance appraisal. Lin et al. (2001) used aptitude treatment interaction design to examine how executive thinking styles affect web-based peer assessment and indicated that students with high executive thinking styles contributed substantially better feedback than their low executive counterparts.

4.2. Adaptive peer assessment

Peer assessment requires cognitive activities such as reviewing, summarizing, clarifying, providing feedback, diagnosing errors, and identifying missing knowledge or deviations. However, each student has an individual learning style and thus has different abilities to assess peers' work. In order to improve rating effectiveness, a methodology for adaptive peer assessment is proposed. The framework of adaptive peer assessment is shown in Figure 8.

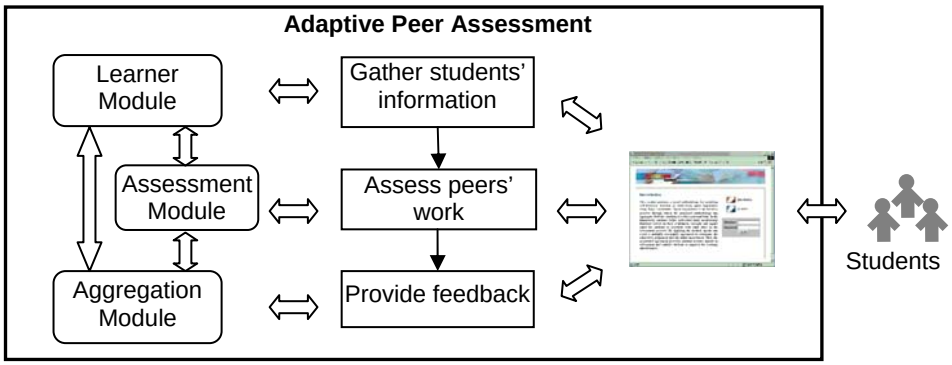

Figure 8. The framework of adaptive peer assessment

The learner module contains the knowledge about classifying students into the appropriate learning styles. Peer reviewers have to fill out the Index of Learning Styles (ILS) questionnaire (Felder and Soloman, 1997) in order to detect their learning styles. The assessment module provides assessment issues such as *Creativity*, *Completeness*, *Execution* and *Security*, and includes all relations between these assessment issues and learning styles. Students can rate peers' work for assessment issues to construct their constraints. The aggregation module considers students' learning styles to adjust the weight for assessment issues, and provides the final rating to the students. The computational function in the aggregation module is described as follows.

$$\textit{Assessment feedback} = \sum_{i=1}^{n} w_{ij} x_{ij} \,/\, \sum_{i=1}^{n} w_{ij} \,, \tag{6}$$

where n is the number of students, x_{ij} is the rating of student i for assessment issue j and w_{ij} represents the weight of student i for assessment issue j in aggregating all ratings according to different dimensions in learning styles.

Equally to the previous section, the Felder-Silverman learning style model (FSLSM) (Felder and Silverman, 1988) was selected due to its appropriateness for the use in adaptive web-based educational systems (Carver et al., 1999; Kuljis and Liu, 2005). As described above, FSLSM characterizes each learner according to four dimensions: active/reflective, sensing/intuitive, visual/verbal, and sequential/global. Considering the four assessment issues *Creativity*, *Completeness*, *Execution*, and *Security* in the calculation process of the assessment feedback, two of the four dimensions of FSLSM are of particular interest: active/reflective and sensing/intuitive.

Active learners prefer to try things out and prefer to work actively with the learning material. In contrast, reflective learners prefer to think about and reflect on the material. Since execution and security deals with actively testing whether the implemented solution works and respectively checking security settings, active learners tend to be more familiar with these issues. Therefore, the importance of the assessment issues *Execution* and *Security* provided by active students can be seen as higher than by reflective students.

Furthermore, the sensing/intuitive dimension plays a central role for peer assessment. Sensing learners prefer to learn concrete material and tend to be more practical. They like to solve problems by standard approaches, tend to check their work carefully, and are considered as more patient with details than intuitive learners. As a consequence of these characteristics, their ratings in *Completeness* are accounted as more important. On the other hand, intuitive learners prefer to learn abstract material. They like to discover possibilities and relationships and tend to be more innovative and creative than sensing learners. Therefore, we assume a higher importance for ratings on the *Creativity* issue. Considering the active/reflective and sensing/intuitive dimensions, the importance of assessment issues is described in Table 1.

Table 1. The importance of assessment issues for individual learning styles

Issues\LS	Active Sensing	Active Intuitive	Ref. Sensing	Ref. Intuitive
Creativity	Low	High	Low	High
Completeness	High	Low	High	Low
Execution	High	High	Low	Low
Security	High	High	Low	Low

The aggregation module considers students' learning styles and aggregates all ratings, and then the final feedback is displayed. By this process, students typically develop a serious attitude towards their coursework. Through considering different learning styles, the proposed methodology is able to flexibly aggregate ratings to improve the accuracy of peer assessment.

4.3. Scenario of adaptive peer assessment

We present the process of peer assessment by a typical scenario and illustrate how learning styles can enhance the quality of assessment results. In this example, four students (student *A*, *B*, *C* and *D*) are taking part in peer assessment. Student *A* submits his project and students *B*, *C* and *D* assess independently student *A*'s project for the specific assessment issues (*Creativity*, *Completeness*, *Execution*, and *Security)*. Figure 9 shows the process of adaptive peer assessment which is divided into the following steps.

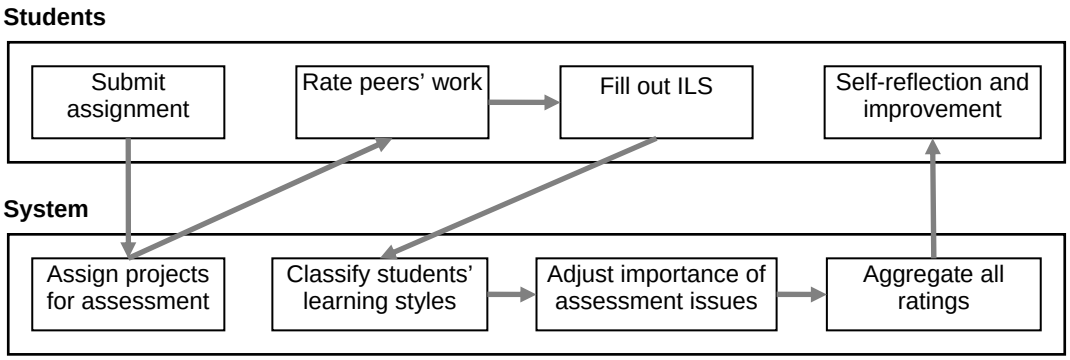

Figure 9. The process of adaptive peer assessment

Step 1: Rating peers' work

The instructor first explains each assessment issue to the students, and then students *B*, *C* and *D* use an 1-10 scales (the value 1 means poor and the value 10 means excellent) to rate student *A*'s project for each assessment issue. Student *B* thinks *Creativity* is 3, *Completeness* is 6, *Execution* is 5 and *Security* is 6. Student *C* thinks *Creativity* is 5, *Completeness* is 3, *Execution* is 6 and *Security* is 7, and student *D* thinks *Creativity* is 8, *Completeness* is 9, *Execution* is 6 and *Security* is 7.

Step 2: Classifying students' learning styles

Students *B*, *C* and *D* fill out the ILS questionnaire (Felder and Soloman, 1997) in order to identify their learning styles. Based on the feedback of the questionnaire, student *B* is found to be an active and intuitive learner, student *C* a reflective and intuitive learner, and student *D* an active and sensing learner.

Step 3: Adjusting importance of assessment issues

According to the learning styles, the importance of assessment issues for each student are:

$$w^{B}_{\text{creativity}} = High,\ w^{B}_{\text{completeness}} = Low,\ w^{B}_{\text{Execution}} = High,\ w^{B}_{\text{Security}} = High,$$

$$w^{C}_{\text{creativity}} = High,\ w^{C}_{\text{completeness}} = Low,\ w^{C}_{\text{Execution}} = Low,\ w^{C}_{\text{Security}} = Low,$$

$$w^{D}_{\text{creativity}} = Low,\ w^{D}_{\text{completeness}} = High,\ w^{D}_{\text{Execution}} = High,\ w^{D}_{\text{Security}} = High.$$

Step 4: Aggregating all ratings

Through considering the importance and aggregating all ratings, the assessment feedback over (*Creativity*, *Completeness*, *Execution*, *Security*) is (4.8, 6, 5.6, 6.6) according to the computational function (6). The final result reduces rating bias based on incorporating individual learning styles and therefore improves the accuracy of peer assessment. Finally, student *A* gets the more accurate feedback to reflect and improve his/her project.

4.4. Experiment

In order to examine the effectiveness of considering students' learning styles in the peer assessment process, we conducted an experiment. We used the peer assessment system to help thirteen undergraduate students to do peer assessment in the course Database System. These students were assigned to implement a database design project. The teams were randomly divided into four groups, where each student assesses the work of his/her group mates and his/her own work. However, students did not know the identity of their group mates.

During the peer assessment process, the instructor asked each student to design a project utilizing database theory that comprised preliminary plan, requirement analysis, conceptual database design, logistical database design, physical database design, and implementation. All students submitted their projects and moved on to peer assessment using the assessment issues provided by the instructor. The instructor also rated the submitted projects.

All students were asked to fill out the ILS questionnaire in order to classify the learning style of each student. According to the results, 4 students were classified as active and sensing students, 3 as active and intuitive students, 4 as reflective and sensing students and 2 as reflective and intuitive students.

Pearson's correlation analysis was adopted to compare the correlations between the resulting ratings of peer assessment and instructor's ratings. Table 2 shows the different results of correlations when using the assessment agent with and without considering learning styles.

Table 2. Correlation analysis between the instructor and students' ratings (*: $p < 0.05$, **: $p < 0.01$)

Assessment issues	Peer assessment without learning styles	Peer assessment with learning styles
Creativity	0.55*	0.57*
Completeness	0.45*	0.62*
Execution	0.53*	0.74**
Security	0.48*	0.69**

According to the results in Table 2, students' assessments considering learning styles are more significantly and positively correlated with the instructor's assessments for each assessment issue. Therefore, the findings indicate that the involvement of students' learning styles can influence the process of peer assessment positively and the final scores are more consistent with the instructor's assessments.

5. Conclusion

This paper introduced different applications in the area of adaptive web-based assessment by reviewing systems developed for readiness self-assessment, performance self-assessment, and peer assessment. These systems show different ways of providing adaptivity and also incorporate different needs and characteristics of students. By improving systems with adaptivity, the assessment can be done more effective and students can benefit more from the assessment.

Regarding adaptive readiness self-assessment, knowledge modelling in the AM I READY project has captured different kinds of counselling knowledge and several models of self-assessment process, and has brought new features to traditional self-assessment online questionnaire system. Those features include flexible questions designing, user oriented or user specific questioning, dynamic and adaptive self-assessment process. Knowledge modelling, representation and reasoning have been proposed and implemented in this project. Functionally, it provides a more effective and nature process to understand and assess its users. It can also provide real time guidance and remedial information to the users, which can be very helpful for the prospective students not only get to know their readiness, but also know how to improve the readiness. The system is currently running and providing online services. However, there are still some works needed to do in the future. A knowledge editor is needed to improve the knowledge modelling and modification. A new change for improving the final representation of users' readiness by statistical information is on the way. A Formal knowledge description and a SQL based reasoning method for AM I READY will be reported in a future paper. Data mining can also be done to analyse the questions and their relations and provide some information to improve the knowledge base. Readiness self-assessment is only the rudimentary step to a general counselling system, which needs more Psychology and Artificial Intelligence technologies and will be very beneficial to E-Learning environments.

The role of performance self-assessment can be seen as an important aspect for accommodating the students' learning styles in web-based educational systems. The proposed add-on to the learning management system Moodle enables the system to provide adaptive courses that incorporate the different learning preferences of students. By presenting self-assessments according to the students' learning preferences, in terms of the position of the self-assessments in the course and the number of recommended self-assessments, students can benefit more from them. Moreover, the students' performance and behaviour related to self-assessments can deliver information about their learning styles which can be used to build a more accurate student model and therefore help to provide more suitable adaptivity. While the add-on and its adaptation features are currently evaluated by a course with about 400 students, further investigations about the concept of improving student modelling by data from the behaviour of students are planned. Future work will deal with using this additional information to dynamically update and verify the initial information about the students' learning styles.

Adaptive peer assessment, which integrates assessors' learning styles into peer assessment, reflects the assessors' abilities and characteristics and therefore provides peers with a fairer assessment. Experimental results show that the accuracy of assessment is improved through considering students' individual learning styles. During the process of our experiment, most students believed that the peer assessment system helped them to reflect on and improve their learning activities. All participants also thought that by relying on adaptive peer assessment, the assessment method was flexible and fair. The aggregation feedback considering students' learning styles indeed contributes to provide students a better quality of assessment. Finally, although the proposed methodology has yielded promising results in improving the accuracy of peer assessment, considerable work remains to be done, including further development of the methodology to allow students to provide their own assessment issues, consideration of other students' characteristics, and large-scale experiments in classes.

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