Combining Self-regulation and Competence-based Guidance to Personalise the Learning Experience in Moodle

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Abstract: Adaptive learning systems aim to address a learner's specific needs, considering factors such as prior knowledge, learning efficiency, learning goals and motivation. Especially in distance education, often directed to adult learners with full-time jobs, it is very important to provide this necessary level of assistance to counteract high dropout rates. This paper describes an approach on how to support adult learners through the adoption of personalisation and guidance in Moodle. The implementation is based on the combination of two pedagogical approaches, competence-based learning and self-regulated learning (SRL). The three-phases approach of SRL (i.e. planning, learning, and reflecting) was used to roughly frame the design of the learning flow, where the individual phases are supported by competence-based guidance and reflection. In this way Moodle is extended from a teacher and course management to a learner-centric system. This work has been implemented and evaluated in the course of a European project that targets vocational training of heat pump installers.

Keywords: Personalised online training, Competence-based knowledge space theory, Self-regulated learning, Learner modelling, Learning object recommendation, Moodle, INNOVRET.

I. INTRODUCTION

Moodle (Modular Object-Oriented Dynamic Learning Environment) is an open source Learning Management System (LMS) which is capable of supporting high levels of interaction, web visibility, online social networking, and knowledge exchange between learners [1]. Moodle includes many features that improve pedagogical quality [2], while assisting teachers and course developers in creating and managing online courses. It supports a variety of different learning object (LO) formats and question types (herein referred to as assessment items (AIs)). Despite the afore-mentioned advantages, Moodle is usually course based and does not cater for the individual needs of students [3]. However, its extensibility (plug-ins and modules) offers a promising possibility to introduce personalised learning support, which gives the learner more freedom to control their own learning process. This caters to the needs of non-homogeneous student groups [4] while taking advantage of, and integrating with the existing infrastructure. In this paper we describe a personalisation approach developed within the scope of the INNOVRET project (Innovative Online Vocational Training of Renewable Energy Technologies) that aims to provide an online training solution for heat pump installers. It combines the benefits of two pedagogical approaches: Self-regulated learning and competence-based learning by means of the Competence based Knowledge Space Theory (CbKST) embedded in Moodle. The CbKST is a psychologically sound framework to represent the organisation of a given body of competences [5]. The resulting competence structure forms a domain model that is used to instantiate learner models [6]. Domain and learner models are essential in providing adaptive assessment and recommendation strategies. However, instead of dictating the learner how to learn, a SRL approach is pursued where the learner can chose learning targets and learning objects. The combination of SRL and CbKST enhances the benefits for the learner by enriching the learning experience with a combination of self-management, reflection and guidance. Following the ideas described in [7] we have designed, implemented and integrated an adaptive learning approach in Moodle, taking into account SRL and CbKST concepts while using the infrastructure of a well-supported Learning Management System.

II. PSYCHO-PEDAGOGICAL APPROACHES

In psychological and pedagogical research about learning there are various approaches that address the best manner with which to enhance the learning process and learning outcome of an individual. Naturally, different approaches have different advantages. In this paper we elaborate on an approach that was conceptually described in [8], focusing on the combination of two very diverse, but not mutually exclusive, learning theories: Competence-based learning and self-regulated learning (SRL).

A. *Competence-based Learning*

In the context of competence-based learning the learning content is adapted based on the learner's initial competence state. Competences that are already available do not need to be taught again, but instead, new competences can be taught. Advanced competence-based learning systems are adaptive in more than one respect – i.e. learning content is firstly, recommended and secondly, assessed adaptively. Therefore, one huge advantage of competence-based, adaptive learning systems is a considerable reduction in time and effort required to learn the content, irrespective of the knowledge domain being taught.

In this Paper, we discuss the use of the Competence based Knowledge Space Theory (CbKST)[5] to model the competences of a learning domain and to define prerequisite relations between them. In addition this approach allows associating learning objects and assessment items with competences, includes methods to adaptively assess the learner's competence state and to recommend learning objects fitting to the current competence state.

In the course of the INNOVRET project we have identified 78 competences and their interrelations, 80 LOs with links to further information and 234 assessment items (AI). LOs and AIs have been created, evaluated and assigned to competences that underlie the heat pump domain.

B. *Self-Regulated Learning*

A very different, but popular view on learning is the self-regulated learning (SRL) approach. While Competence-based learning focuses on the subject domain level, SRL emphasises the learners' own ability to control and regulate each step of their learning process. A common SRL model regards learning as a cyclic process divided into three phases [9]: (1) Forethought (also referred to as planning phase), (2) Performance (also referred to as learning phase), and (3) Self-Reflection. In addition to acquiring domain knowledge, the learner applies meta-cognitive activities when taking control over- and reflecting on learning.

C. *Sythesis of Self-regulated and Competence-based Learning*

The INNOVRET model aims to leverage the benefits of both the Competence-based and Self-regulated learning approaches. The CbKST principles are used to adaptively support the learners in every phase of their self-regulated learning process. For that purpose the CbKST principles are linked to the three SRL-phases. Based on the domain model, the learning content and the assessment items presented to a learner are selected according to the learner's current competence state (i.e. the set of competencies that a learner demonstrates). Selected learning content is presented to the learner in form of recommendations that can be followed or not. Visualisations of the learner's competence state and learning history support reflection and awareness. Given the fact that all recommendations are based on the competence state, the learning process shall be efficient (time and effort) whilst at the same time self-regulated.

D. *Learning Process*

We define a learning process in accordance with the SRL model (Fig. 1) offering Moodle plug-ins to support the three separate phases.

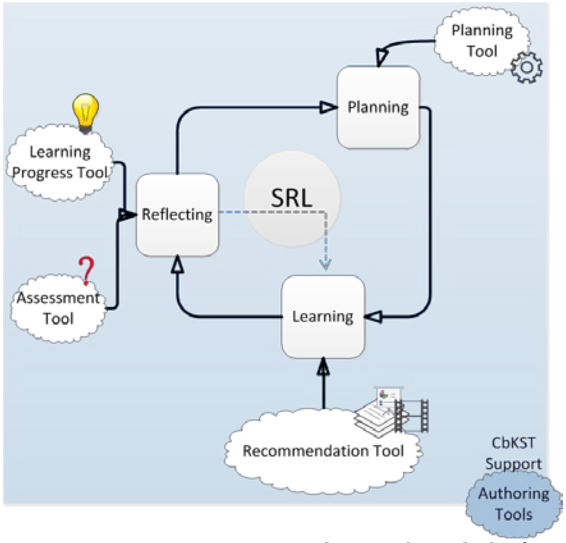

Figure 1: SRL in INNOVRET in relation to the applied software components

Each learning process starts with the selection of a target learning profile (i.e. a set of competences a learner aims to demonstrate after completing the learning process) and an initial assessment of a learner's competence state. This data is used to initialise the learner model. To allow for purposeful support during the learning process we further introduce learning iterations (Fig.2). A learning iteration is defined as the period of time between two complete consecutive assessments. An assessment is only activated for the learner after he/she has engaged with at least one of the relevant learning objects.

After completing the initial assessment the learner model has been initialized with probability values allocated to single competences. The specific learner model is thereby instantiated from the domain model. It consists of competences, interrelation between competences and probability values that indicate the likelihood to which a learner may demonstrate a competence. In the learning phase, LOs are recommended based on probability levels of the learner model that are derived from the CbKST algorithm. In this way LOs are selected that have a medium level of difficulty for the learner. Competence probabilities in the learner model are updated with results of every assessment. This is done by applying the Simplified Updating Rule [10] in a learner's learning profile with positive values for correctly answered questions and negative values for incorrect answers. The newly updated learner model serves as a basis for the next learning iteration.

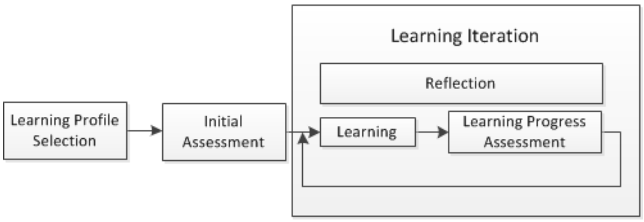

Figure 2: Learning Process consisting of n Learning Iterations

III. Conceptual and Technical Approach

Moodle is not only open source, but also offers extensive community support and therefore represents an excellent platform for adaptation and extension. This section describes how web-services and plug-ins based on the CbKST have been designed and adapted to provide a personalised learning environment in Moodle.

A. The role of the CbKST services

The CbKST service provides the algorithms for LO recommendations and competence assessments and exposes them via a REST interface. It also holds the domain model which consists of competences and their prerequisite relations, with references to LOs and AIs (Fig. 3) as described in section IIA.

The actual LOs and AIs (questions) are stored in Moodle (in Moodle supported formats). An authoring tool has been implemented to assign LOs and AIs to competences of the domain model. With this domain model we retrieve learner models that include probability values of the competences, visited LOs, solved AIs, and the navigation behaviour through the SRL phases. This component offers a REST interface to update the domain model whenever LOs or AIs change, to retrieve AIs according to a learner model (subsections B, D), to update learner models with assessment results, to retrieve LOs fitting a recommendation strategy (subsection C), and finally to manage relevant log data to support reflection (subsection D).

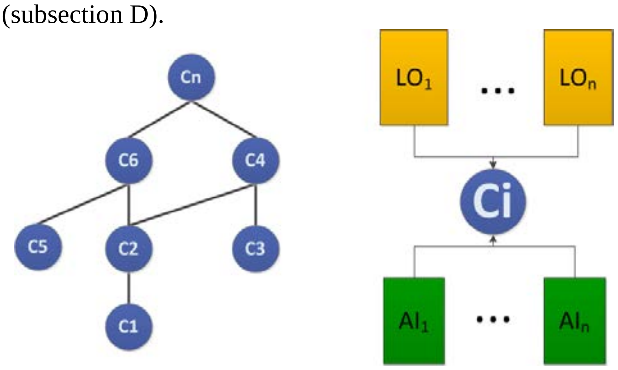

Figure 3: Shows exemplary how competences, learning objects and assessment items relate to each other

B. Support in the Planning Phase

The planning phase in SRL includes strategic planning and goal setting ("Forethought Phase" [9]). According to [3] goal setting can be implemented by defining a set of competences which are expected to be achieved (competence goal) or by defining a set of problems which the learner should be capable of solving. In this case, the system asks the learner to select a target profile that comprises a set of competences.

Competences used in a learning cycle are derived from the gap between a learner's competence goal and a learner's actual competence state. An assessment is required to identify the competences a learner demonstrates at a certain time. The CbKST service enables such assessments by asking not all questions, but only enough to draw conclusions on a learner's competence state. Such inferences can be made by exploiting the prerequisite structure of the competences that allows for the propagation of probability values to not tested competences in the learner model. This information later affords the opportunity to create personalised learning-paths which lead to the intended competence goal [11]. In our approach, the planning phase is supported by the selection of a predefined learning profile and an initial competence assessment. After completing the planning the learner is forwarded to the plug-in's main menu (Fig. 4) where links are presented to access learning recommendations, to complete an assessment, and to reflect on one's learning progress. Functions accessible through this graphical user interface (GUI) align with the definition of a learning iteration. Initially the learner engages with learning activities and by this means, enters the learning phase.

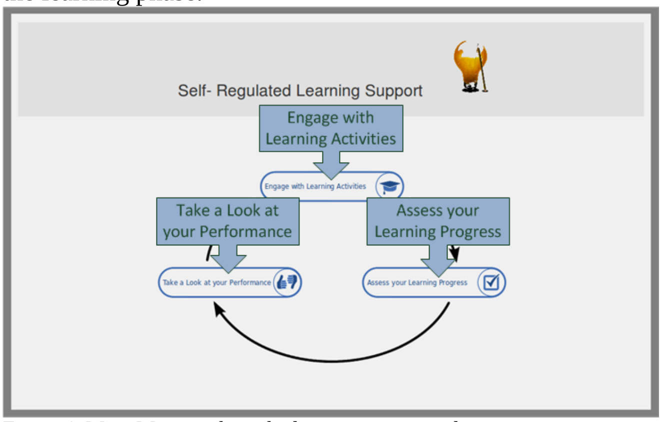

Figure 4: Main Menu - where the learners engage in learning iterations

C. Support in the Learning Phase

LOs are selected based on a learner's competence state (see Fig. 5). The CbKST service recommends those LOs which are neither too easy nor too difficult for the individual learner.

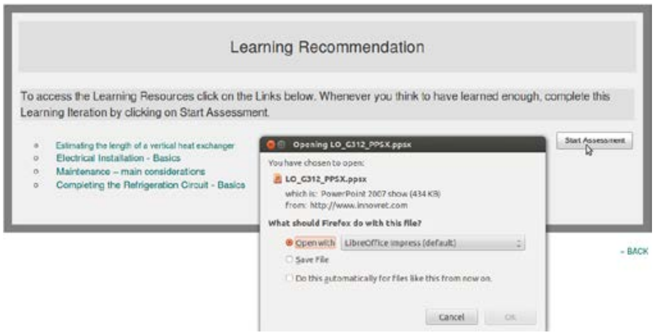

Figure 5: Presenting adaptively selected learning objects to a learner

This is integrated with Self-Regulated learning (SRL) as a combination of guidance (through recommended learning objects (LOs)) and self-regulation (through the free selection of LOs). Whenever learners feel confident about their learning progress they may click on the "*Start Assessment*" button to leave the learning phase and enter the reflection phase.

D. Support in the Reflection Phase

The reflection phase is supported by two different tools, the *learning progress assessment* and the *visualisation of performance* data. The learning progress assessment confronts the learner with questions that are assigned to the competences addressed in the learning iteration. With the outcome of an assessment, the learner model is updated which finalises the learning iteration. Log and performance data will then be available for reflection. As the competence for the recognition of visual information is highly developed in humans [3], visualization plays an important role within the learning process. Fig. 6 shows one of three tabs that are provided to the learner in order to support the reflection phase. It illustrates a learner's performance metrics per iteration: i.e. the percentage of correctly answered questions; the percentage of consumed LOs in relation to recommended LOs; the mean value of all probabilistic competence values described in a student's learning profile. The visual representation of knowledge supports the learner in further planning and evaluation of the ongoing learning process. The visualisation approach followed therefore reports on the learning objects which have been accessed, the results of the assessment questions and the learner's progress within the targeted learning profile.

Figure 6: The reflection phase diagram, demonstrating the percentage of correctly answered question (green bar), consumed learning objects (blue bar) and a mean value of all competence values in the learner's target learning profile.

IV. Evaluation

An evaluation of the software was conducted with fourteen male adolescents currently studying heat pump installation in Ireland. These participants were organised in two groups: one group (the control group) had access to training material via Moodle as learning management system; the other group (the experimental group) used Moodle extended with learning support tools built on CbKST to access the same training material. The learning content covered technical knowledge about heat pumps, their installation, and maintenance. In a session of two hours, these participants had to learn with the system by following an introduction on the overall approach and user interface. After the learning phase they filled out a questionnaire on their learning and system experiences. A researcher monitored them during the usage of the system and made interviews at the end. Furthermore, log data of the CbKST group was captured providing insights on the usage of the system.

The questionnaire contained ten questions (eight for the Moodle group) to be answered on a Likert scale from "strongly disagree" to "strongly agree". The mean values of the results of both groups are displayed in Fig. 7, where the answer range is scaled on values from 1 to 5.

Three of the questions targeted the overall approach, namely the iterative learning process (Q1), the awareness support (Q2), and the guidance support (Q4). The mean values of the CbKST group were above average, where the more specific questions (Q2 and Q4) had better results. In the control group only Q4 was asked, which achieved a poorer result. The two negatively posed questions concerned learning problems, namely: if this approach were limiting (Q3) or stressful (Q5). According to the answers the CbKST approach is less limiting. Further questions targeted the participants' enjoyment (Q6) and the perceived learning success (Q7), which were both above average and better than for the control group. The user interface (Q8) and the content quality (Q10) were above average and similar to the control group. The question, evaluating if the users would like to use a system like this in the future (Q9) resulted clearly above average and was considerably better than for the control group. The participants also reported a few technical problems with the system, which explains the appearance of a better result for Q9.

Observations of the CbKST group by the researcher revealed that the IT skills of the installers play an important role in the way they perceive the system and the entire learning experience. Installers whose IT skills are good or average did not have any problems navigating, using, and interacting with the system, whereas installers who are not used to using computers found the system itself to be a barrier.

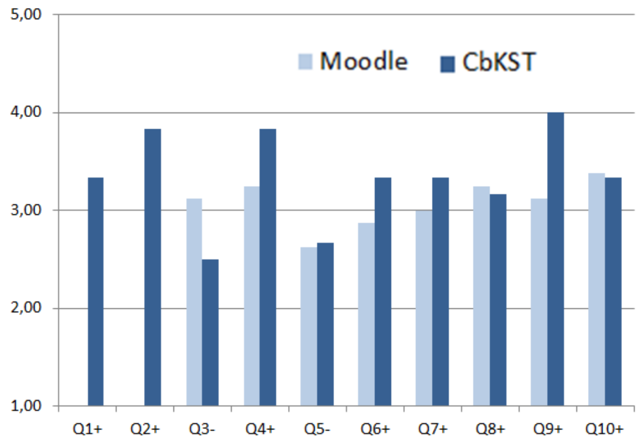

Figure 7: The mean values of the CbKST group (N=6) and the Moodle group (N=8) of the evaluation questionnaire.

This fact is also visible in the rather high standard deviation values between 0.98 and 1.47 for the ten questions. In interviews the participants with proper IT skills stated that the CbKST approach would be good and efficient. However, they found that there is room for improvement regarding the simplicity of the user interface.

According to the log data of the CbKST group the participants, on average have performed 3.2 learning iterations, visited 9.4 learning objects, followed 82% of the recommended learning objects, and answered 9.2 assessment questions. As mentioned earlier, there was a discrepancy between participants with good and poor IT skills, which became also visible in the usage frequency. The fact that users followed 82% of the recommended learning objects shows that the recommendation strategy was appropriate for the participants.

V. Conclusion

In this paper we introduced Moodle plugins to adaptively support and guide learners through a learning domain while trying to promote self-regulation. The approach was developed and implemented within the INNOVRET project that specifically targets the student group of heat pump installers in distance learning settings. It is expected that their knowledge (or lack thereof) varies greatly, and so teaching content to the same extent and in the same order to every student would not make sense. Also, there will be differences in the goals/aims of individual learners. However, a generally valid domain model allows the generation of learner models that serve as basis for personalised guidance (LO recommendation) and adaptive assessment. The recommendation of LOs tailored to a learner's knowledge, is time and energy saving, as well as efficient and motivating. This can lead to the so-called 'flow experience' [12], wherein frustration (caused by over-challenging LOs) and boredom (caused by less challenging LOs) are avoided. The CbKST logic which establishes our personalisation strategy is implemented as a Java Web-service component and can therefore be easily modified, enhanced or exchanged by any other adaptation strategy following the same interface design.

Moodle is not only a rewarding system when developing (open source, modular ...), but is also commonly known and used by teaching instructors [13]. Our systems design took this familiarisation into account using LOs and AIs in the standard Moodle formats. This enables instructors to modify LOs and AIs as easily as in standard Moodle course design. Assigning LOs and AIs to competences is still to be done, but consists of a simple procedure using a provided authoring plug-in [14].

A first evaluation with the project's target group (heat pump installers) left us with quite encouraging results as the CbKST group rated their satisfaction with the system above average and on essential scales higher than our control group.

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