Supporting Students by Integrating an Open Learner Model in a Peer Assessment Platform

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Abstract. An open learner model uses system's representation of the student to support learning and reveal progress. The model contains information regarding learner's characteristics such as level of knowledge, interests, involvement and other relevant cognitive aspects. The current paper presents an example of incorporating an open learner model in a peer assessment platform, more specifically LearnEval, and applying it in the context of a project-based learning scenario in a Web Applications Design course. The student is modeled based on several traits such as competence, involvement and assessment abilities. Furthermore, an aggregated overall score offers a general overview of the student capabilities. To incorporate the open learner model, a *Scores* module was integrated into LearnEval, offering intuitive, friendly and effective visualizations of the scores and a breakdown of the metrics composing them in the form of progress bars, gauges, column bars, trophies and medals. We offer a description of the context where the open learner model was put in practice as well as an example of how a learner could utilize it. An opinion survey regarding the experience with the open learner model was applied to the students at the end of the semester. The findings are encouraging, as the learners found the module easy to use, helpful and comprehensive and they examined it relatively often.

Keywords: Open learner model · Peer assessment · Peer review platform · Student modeling

1 Introduction

Student modeling is a key research topic with important influence on the educational practice. *Learning awareness tools* offer students real-time information regarding their learning [4]. Furthermore, an *open learner model* (OLM) makes use of a machine's representation of the learner as a means to support learning [4] and to reveal student's progress and achievement [11]. The model of the learner encompasses information regarding traits such as student's knowledge, interests, or other cognitive related aspects [4]. The OLM could support students in raising awareness regarding their current level of knowledge, thus they could reflect upon their understanding by bringing up matters that would not have been considered otherwise [7]. Furthermore, the OLM enhances students' meta-cognitive activities such as self-assessment as a result of formative evaluation [14]. Therefore, it is critical to create effective OLM visualization formats

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[11]. A wide range of OLMs have been deployed in various contexts in the last decades as reported in the literature [8, 11, 12, 15, 17]; for instance, in [8] the student and the platform negotiate the system's representation of the learner, while in [17] the student can access his/her Bayesian learner model visualization; in the intelligent tutoring systems field, an OLM can enhance student's reflection [12]. The OLM entails many forms of representation such as skill meters [6] or pie charts [13].

On the other hand, peer assessment (or peer review), represents the process in which learners assess the quality of the work provided by peers based on different review criteria and offer formative feedback, supplemented in some cases by summative assessment [5]. By employing such an approach, the benefits for the instructors but especially for the learners are well-known in the literature [16], such as fostering critical thinking and meta-cognition [10], vital aspects that learners need to be made aware of in order to support and enhance their learning. Therefore, by integrating an OLM into a peer assessment context, the students could further enhance their meta-cognition and reflection abilities, thus achieving a higher level of knowledge.

Hence, we decided to integrate OLM functionalities into LearnEval [1, 2], a comprehensive peer assessment platform that offers various affordances for both learners and instructors. The peer assessment workflow supported by the platform is highly configurable, allowing the teacher to apply different pedagogical approaches and elicit specific skills from the learners depending on the type of the course. On the other hand, the system integrates a powerful reputation system that models learners based on several traits: involvement, competence and reviewing abilities. The platform has been applied with success in several computer science courses with different pedagogical scenarios [3].

The current paper reports on the integration of OLM in LearnEval platform, presenting details regarding the implementation, context and scenario of use, and offering an initial validation based on the students' answers to an opinion survey. The aim is to share our experience of integrating an open learner model in the context of a peer assessment scenario.

The paper is structured as follows. Section 2 offers examples of related work integrating OLM in different contexts. Section 3 describes the implementation of the OLM in LearnEval platform by covering student modeling aspects as well as technical details. Section 4 presents a practical application of the platform, reporting students' experience with the OLM. In Sect. 5 we draw some conclusions and outline directions for future work.

2 Related Work

We start by presenting several contexts where OLM has been applied in various formats.

Paper [15] describes an exercise sharing tool implicitly integrating peer assessment. The role of the tool is to increase students' motivation and interaction and help them learn from each other by detecting mistakes or reusing parts of peers' solutions. The system integrates a reputation system covering two aspects: firstly, each learner has a

personal score indicating his/her perceived usefulness to the community, and secondly, the weight of the student actions depends on the personal reputation score. The student is modeled based on his/her actions within the system, votes collected from the peers and from the teacher, as well as the personal reuse factor. Thus, the system models the learner according to five traits: involvement, usefulness to others, competence on the topic, ability to evaluate peers' solutions and critical thinking. The open learner model comes in the form of a personal page where the student can visualize the personal reputation score as well as the influencing factors, helping the learner to spot the behaviors that need to be changed to obtain a higher grade. Furthermore, the reputation values are translated into verbal descriptions to offer students a better interpretation of the teacher's assessment criteria.

A peer review system applied in various topics ranging from Computer Science to Economics, Literature or Writing that allows students to assess peers' homework is presented in [9]. Each student receives a crowd-grade that depicts both the quality of the homework and the quality of the reviews provided, stimulating students to offer fair and helpful assessments. On the other hand, the teacher can use the crowd-grade as a final grade or fine-tune it. The crowd-grade combines three other metrics: a consensus grade computed based on students' submitted solutions, an accuracy grade that depicts the learner's correctness in assessing peers' work, and a helpfulness grade that represents how useful the evaluations provided by the student were. As in the previous study [15], when computing the consensus grade for a submission, a larger weight is assigned to the reviews submitted by students with a higher grading accuracy. In terms of modeling, the consensus grade is computed based on a technique called *maverage* that discards the highest and the lowest grades assigned to the solution and averages the rest of the grades. The accuracy grade is computed based on an algorithm that compares the grade assigned by the student with the grade assigned by a fully random grader. The students can provide a back review score and give feedback for the received reviews, thus the assessors have an incentive to provide helpful evaluations; the back review scores are used to compute the helpfulness grade. However, no information is provided in the paper about how the student can view the learner model.

A study where 23 engineering students, following an Educational Technology module, can visualize the same open learner models using various perspectives is presented in [12]. The study employed a thirty-question multiple choice web-based test by means of which the learner model is constructed based on the student's understanding of flow control in C programming. The student could view the learner model from four perspectives presenting the same information but in a different style: *lectures view* - listing the topics according to the course, *related concepts view* - presenting a logical and hierarchical grouping of the subjects, *concept map view* - displaying a conceptual link between the topics, and *pre-requisites view* - exhibiting a dependency graph for the topics. The learners found useful the possibility to visualize the four perspectives. Furthermore, they could easily inspect their knowledge and perceived the student model representations as highly accurate. However, the findings show that students had different preferences in terms of views and no perspective was considered better than the rest. Furthermore, no link was found between the view preferred by a student and the learning style, thus the adaptation of the learner model visualization based on the learning style does not appear helpful.

Paper [11] presents and evaluates multiple prototype visualizations for the open learner model integrated in Doubtfire tool. Each group of visual components had a certain role: for examining learning task statistics there were used bar graphs, table listings and pie charts; for inspecting individual learning outcomes there were employed controls such as skill meters, tables, tree maps or word clouds; for offering statistics regarding the class there were utilized controls such as boxplots, fan scales or line scales; supplemented by components for comparing learning outcome achievements at different levels. A survey was applied to 108 students from Swinburne University of Technology. The survey required learners to rate each visualization component on a five-point Likert scale, and additionally to select the preferred visualization. Moreover, interviews were applied to 10 volunteers to further explain the data collected from the survey. The most helpful and preferred visualization was the one comparing individual against group achievement. As noticed by the authors, the students who want to be competitive consider comparing features very useful, as opposed to learners who are exclusively interested about their own achievements and consider such features as not useful. The findings show a positive, strong correlation between the perceived usefulness and the preferred view by the students.

Although the literature reports on various contexts and scenarios where OLMs have been applied successfully, a limited number of papers address the integration of an OLM in the peer assessment context. Even though a part of the existing peer assessment platforms are modeling learners according to different traits, they lack effective mechanisms for presenting the OLM and do not allow students to see at a glance their learning status and subsequently draw insightful conclusions. Therefore, the current paper adds to the literature by extending the research on integrating an OLM in a peer assessment context.

3 Open Learner Model in LearnEval

LearnEval is a peer assessment platform supporting both students and teachers. The instructor can easily manage the peer assessment sessions by creating courses and assignments, configuring various assessment parameters, supervising students' activity, as well as examining statistics and learner models [2]. On the other hand, the students can submit solutions to the assignments, review peers' work, inspect the reviews received as well as access personal learner model and statistics at different levels [1].

In LearnEval the student is modeled based on involvement, competence and reviewing abilities. The involvement is a characteristic of the learner presence and activity into the system, being inferenced from the number of solutions and reviews submitted by the student before the deadline and the number of back-reviews accomplished. The next trait, competence, depicts the level of knowledge and the quality of the solutions submitted by the student, being inferenced from: the grades received from the teacher, the final grades assigned to the submitted solutions and the overall average solution grade, a metric representing the average grade by considering also the missed assignments (i.e., solutions not submitted to assignments are graded with 1). Finally, reviewing skill represents the ability of the student in assessing peers' work, being inferenced from both the average of the back-reviews received from the

peers and teacher, and the accuracy of the submitted reviews. Furthermore, an overall score depicts the general capabilities of the student, thus aggregating involvement, competence and reviewing skills. A direct mapping exists between the scores' values and the grading used by the teacher as both are on a scale from 1 to 10, being intuitive for the student and enhancing the comprehensibility of the learner model [2].

The actions of the students into the system are weighted according to their ability in evaluating other peers: the more accurate the reviews provided, the higher the influence of the actions. Therefore, we decided to split learners into three categories: students with high reviewing skills (HRS), students with medium reviewing skills (MRS) and students with low reviewing skills (LRS). An algorithm was devised to allocate students to the reviewing categories. The learners are sorted in descending order according to their reviewing score and subsequently the first third are allotted to HRS category, the second third to MRS and the last third to LRS. This review category is also made available in the open learner model.

The OLM is integrated in the *Scores* module of LearnEval and offered in two perspectives: textual format (Fig. 1) and graphical format (Fig. 2).

In the textual format there are displayed the raw numerical values for each metric and score respectively. For usability reasons, the presented metrics are grouped in collapsible panels based on the score they affect (e.g., *Involvement scores* panel); thus the student can collapse the panels and view one at a time or expand several of them for parallel comparison.

On the other hand, the graphical format allows learners to examine personal abilities in an easy and comprehensible way using various visual components. From a technical point of view, the components were implemented using Bootstrap and JavaScript programming language. Visually, the competence, reviewing and involvement scores are grouped in three panels, using progress bars to depict the metrics associated with each score. A value of 1 means no activity at all (e.g., no solutions submitted before deadline), 10 represents maximum activity (e.g., the student provided reviews for all the solutions assigned), and 0 means no data is available (e.g., teacher back-reviews average is 0 if the learner did not receive any feedback from the instructor regarding his/her reviews). The value on the progress bar is emphasized by a linear gradient ranging from bright red to dark green. By applying the transient coloring, students can see at a glance their level for each metric, whether the situation is satisfactory or appropriate actions need to be considered. Furthermore, as the metrics affecting a score are represented one below the other, the learner can readily compare the values and pinpoint areas for improvement. Moreover, the students can easily compare metrics between different scores as the panels are displayed in parallel.

In the following section of the OLM, the student can visualize the aggregated scores using gauges. We decided to use such controls for two main reasons: first, it allowed a straightforward distinction between the metrics and the related scores, and second, gauges appear more intuitive for depicting performance than progress bars.

The last section of the OLM is split into two panels: *Overall Score* and *Reviewing Category*. The *Overall Score* panel contains the achieved score represented as a column bar, and optionally an award. We decided to employ a column bar as the overall score aggregates the main skills required for the student. A red coloring of the column bar notifies the learner to be more actively involved in the entire process and provide

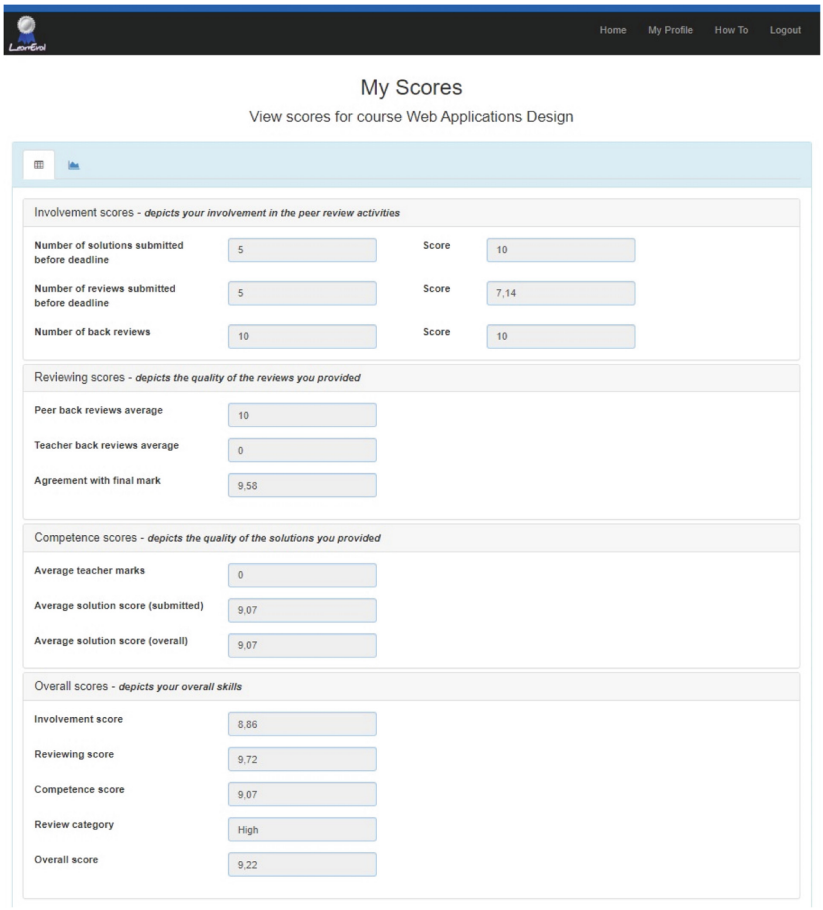

Fig. 1. LearnEval OLM - textual format

solutions and reviews of higher standard, while a green coloring acclaims the quality of the student activity. Additionally, an award is displayed next to the column bar for the students placed on one of the first three positions in terms of overall score: a gold trophy for the best overall score, a silver trophy for the second place, and a bronze one for the third place. The role of the trophy is to offer additional motivation and a gratification for the hard work exhibited by the student.

The *Reviewing Category* panel displays up to three medals according to the reviewing skills of the learner: an HRS student possesses three such medals, an MRS student owns two, while an LRS student owns one. For the students belonging to LRS or MRS categories the medals not yet gained are displayed in dark color, offering an extra motivation for the learners to provide higher quality reviews in order to earn them. Below the medals, the rank of the student in the class is displayed, according to the reviewing score. We decided to show this rank, but not the overall score rank, as the

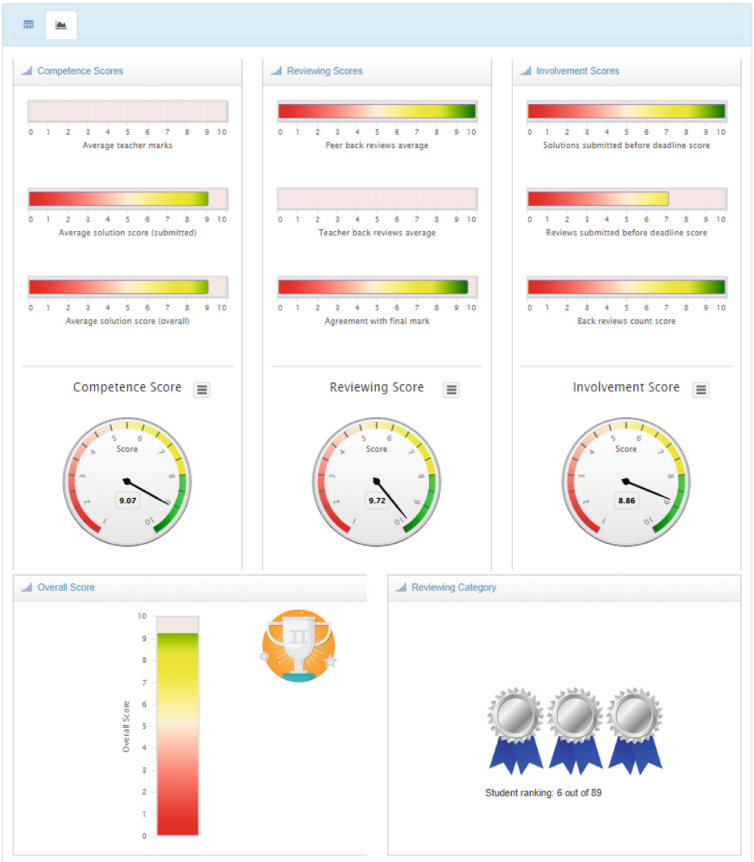

Fig. 2. LearnEval OLM – graphical format (Color figure online)

main aim of the LearnEval platform is to foster peer assessment and help students improve their reviewing skills.

4 Student Experience: Pilot Study

We applied LearnEval peer assessment platform incorporating the open learner model in the context of a Web Applications Design course at the University of Craiova, Romania; the course took place during the second semester of 2018–2019 academic year and involved 109 3rd year computer science students. A project-based learning (PBL) approach was used; the students had to design and implement a fully functional web application on a topic of their choice, such as an online library, an auctions platform, a virtual store, an online management system, a platform for movie reviews etc. Along the semester, the students followed the entire life cycle process of web application development.

In terms of grading, there were four intermediary presentations and one final. Each milestone presentation was complemented by a peer assessment session supported by LearnEval. In this session the students had to upload their solutions (i.e., project deliverables) into the platform before a submission deadline was met. Subsequently, the learners were required to assess three peers' work until a review deadline was reached. In the end, each solution obtained a grade based on the evaluations received and the corresponding students' scores were automatically updated. This peer assessment activity was optional and 89 students (i.e., 82%) chose to participate and register in LearnEval. More details regarding the peer assessment process and results can be found in [3].

The OLM was readily accessible from the *Scores* page of the course in LearnEval. Every time an action affecting a student was triggered or a deadline was reached, the influenced scores were automatically updated by the system. The learner could examine the OLM at any time, but a special case was when a review deadline was reached and the reviewing scores were updated. This was important as the student could see during the semester, at the end of each session, the areas that needed improvement and take remedial actions according to the current OLM in order to prepare for the next session.

For illustration purposes, Fig. 2 depicts the OLM for the student with the second highest overall score at the end of the 4th peer assessment session. By examining the *Competence Scores* panel, the student can readily see that the metrics are all in green as well as the aggregated value, thus the provided solutions were of good quality. Similarly, the values in the *Reviewing Scores* panel are all in green and thus the quality of the provided reviews was appropriate. However, by inspecting the values in the *Involvement Scores* panel the student can notice that the aggregated score is lower than in the previous two cases. By examining the individual metrics, the learner can see at a glance the metric that negatively affected the score, i.e., the number of reviews submitted before the deadline. In the *Overall Score* panel the student can observe the bar in green, signaling a very good overall activity. Moreover, by hovering over the bar, he can see the score value is 9.06. This high overall value allows the student to be the second in his class and rewards him with a silver trophy. Finally, in the last panel the learner can see that he acquired all the three medals, an indication that he is in the top third of his class with respect to reviewing skills (more specifically ranking 6 out of 89). Therefore, based on this OLM, the student can conclude that he has very good competence and reviewing skills, but that there is still room for improvement in terms of the number of reviews submitted on time.

At the end of the semester, the students were asked to fill in an opinion survey regarding their satisfaction and learning experience; 50 students (i.e., 56%) chose to answer this survey. In what follows we discuss the responses to the four questions related to the *Scores* module of the LearnEval system, and implicitly the OLM.

The first question was asking students to report how often they examined the *Scores* module. 34 learners (i.e., 68%) answered that they consulted the module at least to a moderate degree, denoting a relatively high interest from the students. The following question was asking learners to rate the ease of use for the *Scores* module. Most of the students (i.e., 42 or 84%) reported they found it easy or very easy to use. Subsequently, the next question asked students about the reasons for examining the *Scores* module. Replies included: "I considered interesting to see my evolution along the semester", "to

check if I have good scores", "to check if I forgot to do a back-review or upload a solution", "to check my current situation", "curiosity", "to compare my lab grade with the scores from the platform", "to check my reviewing score". Therefore, the OLM allowed students to check their progress in time, their current state of learning, their involvement and reviewing skills, while fostering curiosity and motivation; thus we can conclude that every aspect of the module was deemed helpful by the learners. Furthermore, when asking students what improvements they would like to see in the *Scores* module, many answered that they would not change it, denoting that they were very satisfied with it. Only few students mentioned they would like the scores to be explained in more detail, as they did not entirely understand all of them. Although at the beginning of the semester we provided detailed explanations of the scores, in the future we plan to include more comprehensive descriptions for each score in the LearnEval platform to prompt their recall.

5 Conclusion

The current paper presented the integration of an open learner model in a peer assessment platform, LearnEval. The student is modeled based on involvement, competence and reviewing scores, and each score depends in turn on several metrics. Furthermore, the individual values are aggregated in an overall score. The student can view the open learner model from two perspectives: textual format and graphical format. Whereas the textual format presents the raw numerical values obtained by the student, the graphical format is more versatile by presenting the model using various visual components: progress bars for the metrics, gauges for the aggregated scores, column bar for the overall score, trophies for the best students, as well as medals for depicting students' reviewing skills.

The platform was experimentally used in the context of a Web Applications Design course involving 89 students and following a PBL approach. The results of the opinion survey applied to the students at the end of the semester were very positive; the learners considered the OLM easy to use, they consulted it relatively often in order to check their current progress, reviewing skills and involvement, and they would not make any substantial changes to it.

As future work we plan to improve the *Scores* module in several ways. Firstly, we intent to extend the learner model by integrating other scores depicting student's traits, such as a *Calibration* score that would illustrate student's reviewing skills before the actual peer assessment phase starts. Secondly, we plan to integrate additional graphical components to provide students with different perspectives for visualizing their progress and performance. Finally, we aim to use the LearnEval platform in more courses and instructional scenarios, investigating the impact of the OLM on students' learning experience.

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