Enhancing Project-Based Learning in Software Engineering Lab Teaching Through an E-Portfolio Approach

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Abstract—Project-Based Learning is one of the main successful student-centered pedagogies broadly used in computing science courses. However, this approach can be insufficient when dealing with practical subjects that implicitly require many deliverables and a great deal of feedback and organizational resources. In this paper, a worked e-portfolio is presented as an approach to improve the teaching/learning and evaluation processes in project-based learning environments needing considerable resources. To validate this approach, a practical project-based software engineering course supported by a Moodle-based e-portfolio was designed and taught. The results obtained corroborated the effectiveness of the e-portfolio in practical software engineering teaching; this approach can be extended to similar subjects in other studies and/or curricula.

Index Terms—Electronic portfolio, laboratory education, project-based learning, software engineering education, teaching strategies

I.   INTRODUCTION

Project-based learning has proved a successful approach to teaching engineering courses, as it provides a successful mechanism to help students achieve high-level learning goals and deal with real problem-solving activities. In project-based learning the

instructor has a less central role and students take more responsibility for their own learning, which results in higher student involvement [1].

However, project-based learning falls short when dealing with practical courses that implicitly require many deliverables, a great deal of feedback and organizational resources, and the ability to work productively with others; software engineering labs in computer science studies come into this category. Therefore, although project-based learning pedagogy can be applied in this context [2], additional support is necessary if students are to acquire self-directed learning abilities by developing their knowledge, skills and attitudes within appropriate contexts, and if there is to be an appropriate assessment at the end of the instruction [3].

The use of educational portfolios [4] can help overcome some of these difficulties. In fact, project-based learning can be supported by an electronic portfolio (e-portfolio) approach, which has an advantage over traditional portfolios in terms of storage, access, management, interactivity, real-time functionality, and presentation method [5]. E-portfolios are ubiquitous, portable, electronic knowledge databases that are private, personalized, sharable and easily accessible via the web [6]. In general, the use of e-portfolios facilitates content management, allows students to keep records and connect ideas [7], and facilitates student collaboration.

There is a large variety of e-portfolio types in terms of intended purpose, outcome, process, assessment, and so on [8]. There are also various strategies for the use of e-portfolios for assessment and learning [9]. Some previous approaches have mainly focused on the use of learning portfolios as a part of the course assessment, requiring

students to maintain a reflective logbook that is assessed by teachers [10]. In the area of software engineering learning, in [11] the authors propose an e-portfolio to assess a software project in software engineering education. This e-portfolio included documents and data (such as opinions from customer interviews and other materials collected and summarized by each student group) that teachers analyze to assess the overall student experience across groups, identifying patterns and looking for explanations. In [12], a project-based learning e-portfolio approach was used to assess students' work. This e-portfolio method was appreciated by students, who got weekly feedback about the assignments and had the opportunity to rework their assignments before final submission, which they saw as a great opportunity for self-improvement. In another development, the use of wikis has grown rapidly in all areas of collaborative work, facilitating the efficient sharing and optimization of knowledge gained by carrying out software projects, and allowing these to be assessed by the teacher [13]. However, in general wikis provide less interactive elements than e-portfolios, and thus are less attractive due to the limited facilities they provide for learning and automatic assessment.

An e-portfolio, as commonly used for educational purposes, generally consists of blogs, videos, a diary, lightweight documents and similar material. However, this use of the e-portfolio does not fit well with what is required in practical computer science courses, where much more specific content and functionalities must be included in order to provide rich project-based learning elements. The e-portfolio, as used in the context of this work, can be defined as:

- A mechanism to allow students to carry out a software project, addressing each phase collaboratively with other students, obtaining appropriate feedback from instructors, and conducting self-reflection on their own work.

- A mechanism to allow instructors to monitor, assess, and provide richer feedback to students in order to improve teaching/learning and assessment in a continuous evaluation process typical of practical software engineering courses.

This paper proposes an explicit complement to enhance project-based learning strategies, when dealing with open-ended macro problems. Such problems are very common in senior courses in Computer Science curricula oriented to teaching lifelong learners via real-life problems, and are found in advanced software engineering labs. This paper hypothesizes that it is possible to use a worked e-portfolio to improve teaching/learning and evaluation processes in project-based learning environments involving a lot of deliverables and organizational resources. In this study, based on an existing software engineering lab course using project-based learning at the Escuela Politécnica Superior in the Universidad Autónoma de Madrid, some common problems were identified and overcome by using a Moodle-based e-portfolio to improve the teaching/learning and evaluation processes. This approach was assessed on a cohort of 56 students who took this course, and then completed a test on the topics covered in the study. This paper reports on this experience and the results obtained; these results can be broadly extended to similar courses and curricula.

This paper is structured as follows. Section II presents the context of the course, the related problems and the solution proposed: the implementation of the e-portfolio

approach. This is evaluated in Section III, and then discussed in Section IV. Finally, Section V reports the main conclusions and lays out future work.

II.   PRACTICAL SOFTWARE ENGINEERING

The learning process in software engineering courses is largely inductive. Starting from an initial problem statement and specific material, students begin a software project and progress through its different phases. In every project phase, students produce various deliverables, using specific tools (diagram and CASE tools), for the instructor to evaluate. In this learning style, the continuous refinement and acquisition of high-level knowledge are essential as work continues.

A.   *Highlighting Problems in Software Engineering*

Some significant problems were encountered, including the following:

- Due to changes in Spanish university law, the course had to be split into two different courses, Software Engineering I and Software Engineering II, with different teachers and diverse assessment criteria.

- Since there was no common rubric across these courses that provides consistent and detailed quantitative evaluation results for student deliverables, there was significant variation between groups. The high number of teachers (a total of 11) and class groups involved, and the many evaluation elements in the practical deliverables, made it difficult to arrive at a convergence between the scores given by each teacher in evaluating deliverables.

- Feedback received by students from the assessment of their practical deliverables was not consistent. In most cases, only a numerical grade was given for each deliverable; the lack of explicit mechanisms to trigger the students' auto-evaluation or self-reflection made it difficult to ensure continuous and autonomous learning.

B.   Proposed Solution

These problems were the motivation for a substantial change in the organization of the software engineering labs, which incorporated more efficient group management and normalization mechanisms to improve continuous learning and pedagogic feedback in a project-based learning approach.

The change mechanism was the incorporation of the e-portfolio, designed to help students in their development of a software project to be evaluated by instructors. Essentially, the approach consisted in specifying a set of working documents divided into sections for each project phase. For each project phase students submit tasks showing their work and evidence of learning for evaluation by instructors, who provide appropriate feedback to facilitate the teaching/learning process. In addition, students' being responsible for their own learning encourages independent learning. The e-portfolio itself serves as an evaluation mechanism, since the student maintains a diary of his/her achievements as well as a personal reflection document, covering her/his work expectations, knowledge gained, project phases completed and areas for improvement.

C.   Towards the Change

The steps in accomplishing this change were:

1) Methodological study of the implementation of the e-portfolio in both software engineering courses. A comprehensive study of how to implement the e-portfolio in both subjects was conducted over several months, specifying commonalities and continuity, and agreeing structural aspects of the deliverables, deadlines, dates and milestones. The assessment for the e-portfolio was agreed, specifying its percentage weight in the final course grade. Rubric items were also created to assess each deliverable, including the self-reflection document.

2) Technical study of using Moodle to create an online portfolio. The extensions and capabilities of the Moodle e-learning platform were analyzed. Since it was not possible to modify the institutional version of Moodle, or to integrate new modules, it was agreed to implement the e-portfolio using the existing resources in the current configuration of Moodle, and to increase interoperability by defining specific protocols to be followed by teachers and students when working with the e-portfolio. The e-portfolio structure thus included headings, contents, monitoring and feedback mechanisms, rubrics to assess each deliverable and specific tasks that provided students with material and submission procedures.

3) Application and technical monitoring of the e-portfolio over the academic year. During this period, activities consisted of setting up the e-portfolio, training participating teachers and creating the student groups and teams. Teams were assembled by means of an ad-hoc questionnaire where each student could

choose the team and the partner to work with. During this time of implementation and monitoring, there was a periodic review of each student e-portfolio, providing appropriate feedback and requiring some level of self-reflection for each deliverable.

4) Assessment of each student e-portfolio. This was made according to the rubrics designed to evaluate each deliverable. Correction rubrics implemented on Moodle included a specific section to evaluate self-reflection documents, improving student self-learning and providing a detailed feedback of her/his work. General results for this issue will be briefly summarized at the end of Section IV.

5) Assessment of student perceptions of the e-portfolio. This was carried out through a student satisfaction questionnaire, whose results will be analyzed in Sections III and IV.

D. *E-Portfolio Implementation for Software Engineering Labs*

The teachers involved held discussions to agree on deliverables, milestones and requirements, and to ensure their continuity across software engineering courses. An agreement was reached to work on a single problem statement for the development of a complete software project comprising a set of deliverables included in the e-portfolio.

Fig. 1 shows the design of the e-portfolio approach, comprising different elements that can be basically divided into student-focused (left panel) and teacher-focused (right panel) content. Fig. 1 depicts the content (appearing as pages) and functionalities (marked with a

gear) created in the e-portfolio, where student-focused elements provide information on the software project deliverables and schedule, a self-reflection document, and a student manual giving the principal procedures to use in the e-portfolio activities, as well as other course-related documents. The e-portfolio was programmed with automatic alerts and calendar events to help students submit their work on time, as well as some basic set-up options to configure the environment. A teachers' manual with the principal procedures to manage the e-portfolio was included, as well as other specific functionalities for teachers. Some existing content and functionalities shared by both students and teachers were the correction rubrics and feedback, the questionnaires for composing teams and evaluating the experience, and interactive functionalities such as a forum, news and an on-line chat room to encourage tutorials and provide teacher-student interaction. Other practical documents, references and introductory information were also included in the e-portfolio.
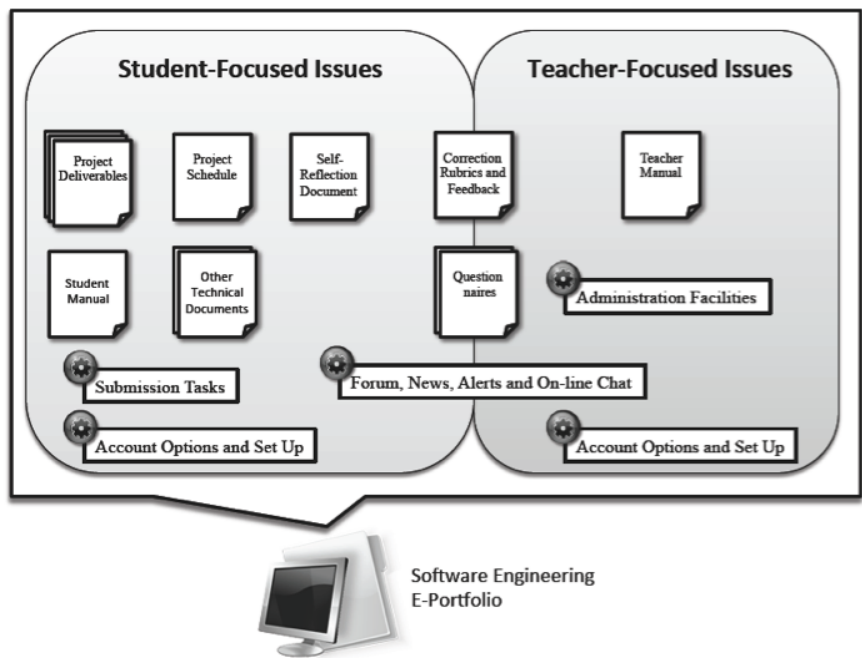
Fig. 1. E-Portfolio design for Software Engineering, showing the student-focused and teacher-focused elements. The rubrics, questionnaires, and forum elements are shared. The elements are categorized into content (shown as pages) and functionalities (shown as gears).

The institutional version of Moodle was the platform chosen to support the implementation. This facilitated the use of some common-built functionality such as account configuration, content management and scheduling, task programming and message distribution. This also made it easy for the students, as they had already used Moodle in other courses.

To assess the student e-portfolios, various rubrics were implemented by scoring and weighting the sections and categories for every deliverable to be evaluated. The Moodle rubrics comprised categorized columns to specify each item's score, range and percent, with a final column including more detailed feedback for each rubric item. The development of partial deliverables, along with the rubrics, solved some of the problems previously mentioned, mostly related to the lack of homogeneity in assessment criteria. This continuous improved feedback to students, and the continuity in designing a software project, enhanced students' assimilation of strategic skills and learning goals much more efficiently than before. Additionally, the e-portfolio not only communicated quantitative assessment information, but also gave qualitative information on individual and team practicals, and suggested improvements to consider in future submissions; these feedback mechanisms also contributed to achieving a better continuous learning process.

Each student had to complete personal reflection documents for evaluation. These documents helped students to reflect on their work and on the learning process, and to highlight their expectations and the key knowledge they had acquired.

III.   EVALUATION

The assessment goal was to evaluate the suitability of the changes and techniques adopted, and to compare the academic results with those obtained in the past.

A.   Evaluation Method

The evaluation method was a student satisfaction survey. The first part of this questionnaire was based on a previous study measuring user satisfaction with the e-portfolio as a tool [14], with the assessment instrument being specifically adapted for this particular case. The second part of the questionnaire, adapted from SEEQ (Students' Evaluations of Educational Quality) [15], was used to assess the teaching-learning and evaluation processes. The SEEQ questionnaire is widely used in academic evaluation to measure valuable psychometric characteristics such as reliability, validity, internal consistency, and the like.

The final questionnaire contained 30 questions grouped into six categories, or dimensions. An additional open general question allowed the students to make additional comments. The six dimensions used to assess the suitability of the experience were:

1. Capacity as an educational resource

2. Feedback

3. Self-Assessment

4. Teacher-student interaction

5. Student-platform interaction (User Interface)

6. Teaching/learning process

The answers to each question were measured on a Likert scale: 1 - Strongly disagree, 2 – Disagree, 3 - Neither agree nor disagree, 4 – Agree, 5 - Strongly agree.

B. *Participants and Procedure*

The on-line questionnaire was completed by 56 undergraduate Software Engineering lab students, 49 men and 7 women, all aged from 22 to 25 years old (M=23.5, SD=1.15). The questionnaire was published in the Software Engineering e-portfolio site, and students were given a week, at the end of the lectures, to complete it.

IV. RESULTS AND DISCUSSION

In order to measure the reliability of the questionnaire results, the Cronbach's alpha was calculated. The questionnaire used for this study obtained a reliability value of 93% (α = 0.93) for the 30 items included. Consequently, it can be concluded that the questionnaire had an acceptable (considered from 80% onwards) level of reliability.

Response Percentage for Each Dimension

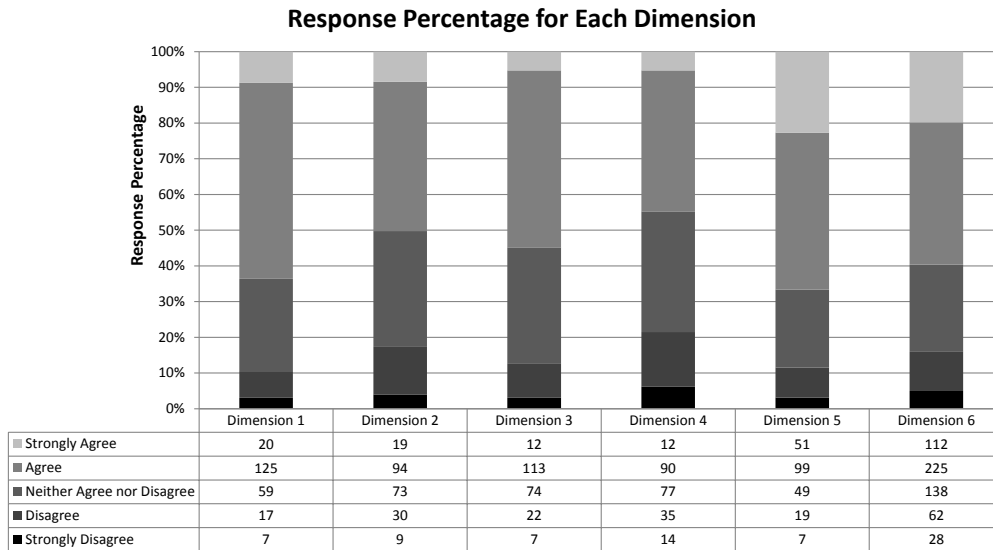|	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6
▨ Strongly Agree	20	19	12	12	51	112
▨ Agree	125	94	113	90	99	225
▨ Neither Agree nor Disagree	59	73	74	77	49	138
▨ Disagree	17	30	22	35	19	62
■ Strongly Disagree	7	9	7	14	7	28

Fig. 2. Results of the student survey in terms of response percentages for each of the dimensions analyzed. Responses are categorized into a Likert scale ranging from 1 - Strongly Disagree to 5 - Strongly Agree.

Fig. 2 shows a summary of the results obtained. Most of the students answered all of the questions, although some left a few blank. Fig. 2 shows the number and percentage of responses to the questionnaire (on a Likert scale ranging from 1 - Strongly Disagree to 5 - Strongly Agree) based on the total number of responses to each of the dimensions evaluated. In general, as shown in Fig. 2, students perceived the e-portfolio experience as positive, and they appreciated the e-portfolio as a valuable resource in the teaching/learning and evaluation processes. This fact is reflected in the percentage of the most positive responses: those with scores 4 (agree) and 5 (strongly agree) were 57% of all the responses collected, while neutral responses (3 - neither agree nor disagree) represented on average 29% of all the responses. Finally, negative answers (1 - strongly

disagree and 2 - disagree) only represented an average 14% of all collected responses. All in all, positive values were observed in most dimensions:

- Dimension 1: students agreed with the perception of the portfolio as a pedagogical resource, noting that they found it useful, practical and systematic, and that they had an average degree of motivation to use it in general. The average value for this dimension was 3.54 with a deviation of 0.85, representing 70.83% on a percentage scale.

- Dimension 2: students appreciated the useful feedback provided by the electronic portfolio. On the other hand, the degree of feedback received was perceived as being average, and varying greatly depending on the class group and that group's teacher. The average value for this dimension was 3.41 with a deviation of 0.92, representing 68.35% on a percentage scale.

- Dimension 3: students agreed that the portfolio was a useful resource in the self-assessment process. They considered it as a regular and constant medium to obtain valuable information, although they probably had a rather low perception of the usefulness of the reflection document in general. The average value for this dimension was 3.41 with a deviation of 0.84, representing 68.33% on a percentage scale.

- Dimension 4: students agreed that the e-portfolio provided a mechanism to improve basic interaction, but they paid less attention to the e-portfolio as a quick communication platform to encourage teacher-student interaction. It is worth noting that while the average was low in this dimension, the standard deviation

was higher than in other dimensions, having different values depending on the class group. The average value for this dimension was 3.17 with a deviation of 0.97, which represented 63.54% on a percentage scale.

- Dimension 5: students generally agreed that the e-portfolio is easy to manage, navigate and learn, but they criticized its efficiency in terms of the bottlenecks that sometimes occurred, depending on the network traffic and the number of connections. The average value for this dimension was 3.71 with a deviation of 0.93, representing 74.36% on a percentage scale.

- Dimension 6: (this dimension corresponds to the results of the annual SEEQ questionnaire used to evaluate the quality of the teaching/learning process). The experience was perceived as valuable to achieve a better understanding of the subject and greater involvement with teachers. Students also appreciated the quality and availability of material published, the overall assessment of the deliverables and the perceived utility. The average value for this dimension was 3.59 with a deviation of 0.86, representing 71.91% on a percentage scale.

Student Survey Over a Multi-Year Period

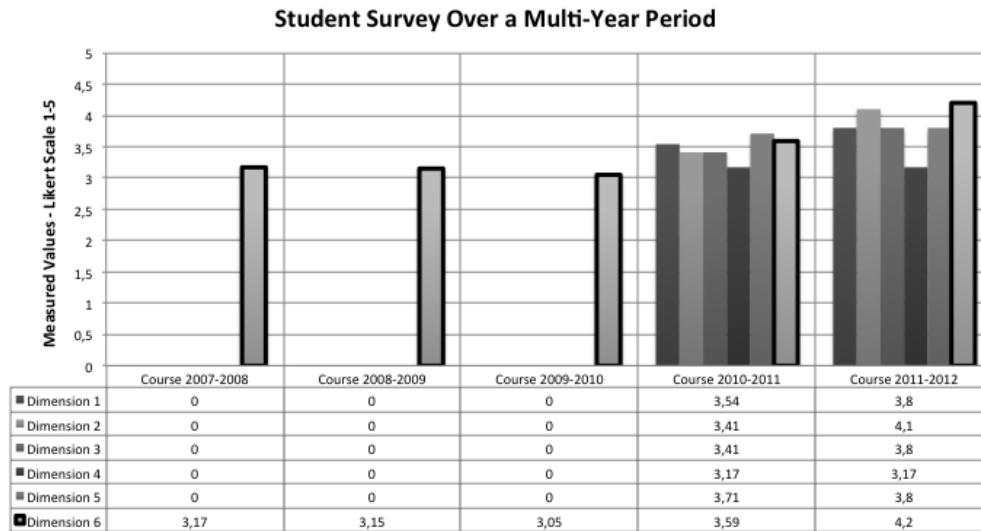|	Course 2007-2008	Course 2008-2009	Course 2009-2010	Course 2010-2011	Course 2011-2012
■ Dimension 1	0	0	0	3,54	3,8
■ Dimension 2	0	0	0	3,41	4,1
■ Dimension 3	0	0	0	3,41	3,8
■ Dimension 4	0	0	0	3,17	3,17
■ Dimension 5	0	0	0	3,71	3,8
◨ Dimension 6	3,17	3,15	3,05	3,59	4,2

Fig. 3. Student satisfaction survey over a period of five course offerings. The 2007-2008, 2008-2009 and 2009-2010 courses are from before the use of the e-portfolio. Dimension 6 is represented by a thicker line to denote the upward trend over this period.

The results previously analyzed correspond to the 2010-2011 academic course offering, when the e-portfolio was implemented and evaluated for the first time. To complement this analysis, Fig. 3 depicts the average values of the aforementioned dimensions over a period of five academic courses. As shown in this figure, only the last two academic years (courses 2010-2011 and 2011-2012) include all the dimensions reported, as they correspond to courses where the e-portfolio was used. In contrast, the three years before the use of the e-portfolio (2007-2008, 2008-2009 and 2009-2010) only include the Dimension 6 evaluation, corresponding to the teaching-learning process evaluation obtained from the SEEQ institutional questionnaire. As shown in Fig. 3, there is a clear increase in all dimensions since the e-portfolio was implemented. Note the upward trend in Dimension 6, represented with thicker-line bars in Fig. 3, which has a cumulative increase

of 27% from 2009-2010 (before the use of the e-portfolio) to 2011-2012 (with the use of the e-portfolio). In addition, the other dimensions studied also increased in the current course (2011-2012) over course 2010-2011, with a 7% increase in Dimension 1, 17% increase in Dimension 2, 10% increase in Dimension 3 and 14% increase in Dimension 6. Only Dimensions 5 (2% increase) and 4 (0% increase) show a low increase and remain unchanged over these academic period for the reasons explained above.

This increase in student satisfaction has been complemented with better student grades; there has been a 40% increase over previous years in the number of students passing the course, and a 30% increase in the rate of students obtaining better grades.

V. CONCLUSION

This paper reports a proposal for improving teaching/learning and evaluation in software engineering labs, which seeks to improve project-based learning pedagogy in engineering environments. This approach was implemented in software engineering labs at the Escuela Politécnica Superior in the Universidad Autónoma de Madrid, with 56 senior-year undergraduate students and instructors.

Various innovations to the existing methodology were proposed to improve the teaching/learning and assessment processes in practical courses focused on project-based learning pedagogy, to inculcate higher-level skills in senior-year students.

A summary of the improvements made includes:

- The development of a common problem statement for all software engineering courses, ensuring a reasonable continuity in the progress of software projects.

- The implementation of a suitable e-portfolio to facilitate the teaching/learning and evaluation processes, providing continuous feedback to students in all phases of their software project, and including a detailed self-reflection document.

- The control of collaborative work by setting milestones, controlling cooperation between team members, and fostering self-reflection. This also enabled students to acquire social skills and face real project-based problems.

The evaluation results from a student survey validated the changes accomplished. Academic results also showed a significant improvement, with an increased pass rate. Also, an analysis of results over five courses offerings, before and after the use of the e-portfolio, show an upward trend in student satisfaction and in their overall perception of the teaching/learning and evaluation process.

All the course instructors meet at the end of every semester to analyze that semester's course offering. Most of the instructors agreed that the implementation of the e-portfolio had achieved progress in the software engineering labs; they reported a clear improvement in homogeneity thanks to the functionalities implemented in the e-portfolio, a reduction in the average disparity per group in corrections, and improved feedback and reflection overall. As a negative point, all instructors reported an increase in their workload with the new system, in particular when filling in the rubrics and writing detailed feedback to students.

Overall, it can be concluded that introducing a Moodle-based e-portfolio approach in the context of project-based software engineering labs provided positive results, yielding an

explicit improvement in the project-based learning pedagogy by improving the teaching/learning and evaluation processes.

Future work is expected to extend these results to other similar undergraduate engineering courses using project-based learning pedagogy. The e-portfolio content will also be improved to include intermediate evaluation tasks that may yield interesting learning information.

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