AC 2012-3237: AN EXPERIENCE USING REFLECTION IN SOFTWARE ENGINEERING

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An Experience Using Reflection in Software Engineering

Abstract

This paper reports the results of a case study where two different reflection mechanisms were used in a couple of graduate courses in the area of software engineering. A learning journal was used in a Software Testing course whereas a two-part reflection questionnaire was used in the Software Quality Assurance course. We evaluated the reflection mechanisms from the student's perspective by means of a survey, and from the teacher's perspective through a qualitative assessment of observed strengths and limitations. We analyzed some of the results obtained from implementing both approaches and reach some conclusions on how to improve our reflection method.

1. INTRODUCTION

There are three common ways in which 'reflection' is used and understood [9]. The first one is that reflection happens between the learning process and the representation of that learning. The second is that reflection has an implying purpose, i.e., we reflect consciously with the aim of attaining a useful outcome. And the third one is that reflection emerges when processing issues for which there is no obvious solution.

John Dewey, an American philosopher, psychologist and educator, is often cited as the father of modern critical thinking theory, which was originally called 'reflective thinking' [3]. Dewey defines reflective thinking as an 'active' process, in which we think things through, raise questions and find relevant information for ourselves, as opposed to receiving information from someone else in a passive way [3]. The key principles underlying Dewey's approach to reflection are the need for 'perplexity' (state of doubt or uncertainty), the sense of goal orientation, and the notion of testing (which later derived into the experiential learning approach) [9]. Dewey believes that there is a close link between reflection and learning, as evidenced in his quote "We do not learn from experience…we learn from reflecting on experience."

Building upon the work of Dewey and others, David Kolb, an American educational theorist, laid the foundations for the Experiential learning theory (ETL) [8], which is a model of the learning process that emphasizes the central role of experience in learning and development. ETL defines learning as "the process whereby knowledge is created through the transformation of experience." The experiential learning cycle developed by Kolb [7] consists of four stages: concrete experience, reflective observation (where the learner consciously reflects on the experience), abstract conceptualization (where the learner tries to assimilate and distill her reflections into abstract models or theories), and active experimentation (where the learner tests her models and theories with new experiences) [8].

Learning journals, diaries and portfolios are increasingly used in higher education to facilitate and to assess learning. They may be highly structured or free, but regardless of their shape and form, they generally seem to be helpful in personalizing and deepening the quality of learning and in integrating the learning material [10]. The distinction between learning jour-

nal and other types of writing is that "…it focuses on ongoing issues over time and there will be some intention to learn from either the process of doing it or from the results of it." [10] Some of the reasons why we can learn from journals are [10]: (*i*) journal writing is a process that accentuates favorable conditions for learning, (*ii*) journal writing encourages reflection and reflection is associated with deep learning, (*iii*) writing in a journal encourages meta-cognition, and (*iv*) the act of writing is associated with learning or the enhancement of learning.

There were two main motivations for introducing a reflection mechanism in our courses. First, we wanted to increase students' engagement in the courses given that there had been a declining student interest in the courses offered by the Master's Program (evidenced by a decreasing number of students taking courses each semester). In response to this situation, we decided to adopt an "active learning" approach in our courses, including the use of reflection mechanisms. Second, we wanted students to achieve a deeper and more enduring learning from our courses (rather than a superficial, short-term one), and inspired on Kenneth Bain's ideas, we decided to try two implementations of student reflection, namely a learning journal and a reflection questionnaire.

Previous experiences on the use of reflection in engineering have been described by Gillet [4], Kelly [6], and Walther[12]. Previous work on learning portfolios has been described by Brown [1] and Chang [2]. The use of wikis to support learning in Computer Science has been reported by Hamalainen [5] and Tsai [11]. Most of these works have been developed and studied at the undergraduate level only. The contribution of our work is to report on two experiences using reflection at the graduate level, thus expanding the context where reflection can be used.

Walther et al. [12] propose a framework of emotional indicators to support student reflection on critical learning incidents. They state that despite the value of reflective journals for learning, there are still difficulties in fostering reflective thought in students, and they conjecture that this is partly due to a lack of specific guidelines to initiate deliberate reflection. Therefore, they address this challenge by developing a framework of emotional indicators that accompany critical learning incidents which can be used to trigger recall and reflection. They propose five categories to organize the feelings according to the learning context they occur in: novelty, challenge, progression, exploration and insight. The framework also includes levels of manifestation of the emotions, in particular, task, others, context, and self. Based on experiences from focus groups that utilized the framework, they found that students' reflection allowed them to recognize specific aspects of their learning but also some insights relating to the process of identity formation. Also, the emotions associated with the learning experiences provided an intuitive access to meaningful reflection.

Kelly et al. [6] report on their experience with class reflections in an introductory materials science and engineering course at Arizona State University. Their work aimed at answering the question "How can we use class reflections to support student learning, attitude, and retention?" After each class period, students were asked to fill out a Class Reflection about what interested them, what they found confusing, and what they found most valuable. In order to measure conceptual learning gains, the instructors created pre and post Topical Module Assessments. The authors evaluated in depth the records of six students which were representative of general class trends. They claim that the use of classroom reflections support-

ed student learning, attitude, and retention. The type of reflection we used is quite similar to the one used by these authors, except for two aspects: the frequency of reflections (they ask students for a reflection after each class, but we do it less often); and the moment when those reflections take place (at the end of the class period in their case, and out-of-class in our case).

Tsai et al. [11] presents a case study of using wiki web sites for collaborative learning in a junior-level course (Introduction to Software Engineering) at Arizona State University. They based their approach on Web 2.0 principles including the Web as platform, harnessing collective intelligence, data are the next Intel Inside, and rich user experiences. They report that their approach has enhanced the educational experience and improved student performance. It also increased motivation and participation, improved peer support for learning, improved accessibility of learning, improved learning results, and increased self-directed learning activities/skills. One of the differences between their work and ours is that their wiki web sites are public, with the spirit of sharing their knowledge base and encouraging peer-evaluation (through ranking of the web sites).

Hamalainen et al. [5] present their experiences using a wiki platform in a telecommunications course at Lappeenranta University of Technology. This wiki platform served as a repository for public learning diaries, homeworks, and a wiki book. They mention positive and negative aspects of using the wiki model. Perhaps their most promising result (based on a web-questionnaire) was that about a half of the students were planning to use the wiki to prepare for the exam and also planned to use the material produced for the wiki later for their studies. On the down side, they admitted that plagiarism and cheating is always a concern when content is shared. Their work also differs from our in that their personal learning diaries are public, whereas ours are private.

Gillet et al. [4] describes a collaborative web-based experimentation environment introduced at the Ecole Polytechnique Fédérale de Lausanne. A key component of this environment is the eJournal, a Web service that enables the collection and sharing of preparatory notes and experimental results with both peers and teaching assistants. It has proven to be an efficient means of promoting active learning within a flexible learning scheme. The eJournal's main feature is to sustain the continuity of interaction among the learning partners (students, professors, and teaching assistants). Their work differs from ours in the purpose of the journal because in their case the eJournal is an augmented version of a hand-written lab journal that students use to keep track of their experiments and results. In our case, the journal is a reflection mechanism centered on the students learning process throughout the course.

Brown [1] performed a study that aimed to describe adult students' perspectives on the learning that resulted from their creation of an experiential learning portfolio, at Barry University's School of Adult and Continuing Education (ACE) in Miami, Florida. Their major findings were: an increase in the participants' self-knowledge after portfolio development; a greater recognition of the value of learning from work and from mentors; and improved communication and organization skills plus a greater appreciation of the role of reflection in recognizing learning. Their experiential portfolio differs from ours in that it intends to document prior student learning from professional and community activities, and it is targeted for adult students. Our student population consists of usually young graduate students, and

the learning journal aims to document the learning process that took place in a specific course.

Chang [2] describes the implementation and evaluation of a web-based learning portfolio (WBLP) which helps record, display, search, and analyze student learning process data at the National Taipei University of Technology. The WBLP system provides functions for students to browse and assess the learning progress and accomplishment of their peers, as well as for teachers to understand the student learning process, provide feedback and interact with students. The results of the evaluation show that most students consider the system to be helpful in enhancing the learning process, understanding the learning outcomes, and providing chances for displaying and improving works.

The rest of the paper is organized as follows. Section 2 describes the context of the courses. Section 3 presents the methodology. Section 4 discusses our findings. And Section 5 concludes the paper and outlines our plans for future work.

2. THE COURSES CONTEXT

The two graduate courses where we experimented with reflection are Software Testing (ST) and Software Quality Assurance (SQA). They are both part of a group of several software engineering courses regularly offered by the Master of Science Program in Computer and Information Science at our university, as shown in Table 1. They are 4-credit-hour courses each, with 64 hours of class time in a 16-week semester, and a 2-credit-hour co-requisite lab course where students put theory into practice by developing a large practical project with several deliverables. The classes meet once a week for 4 hours, with 10-minute breaks every hour. All courses at our university have the same grading scale: 0 to 10. Students require a grade of 7.0 or higher to pass the course.

Table 1. Our graduate-level software engineering courses.

Course	Number of times offered (since 2000)	Use of reflection
PF-3866 Software Testing	3	Yes (one time)
PF-3880 Software Quality Assurance	1	Yes (one time)
PF-3319 Software Development Standards	6	No
PF-3824 Software Metrics	6	No
PF-3375 CASE Tools	6	No
PF-3311 Software Process Management	1	No
PF-3363 Modern Software Process	2	No

2.1. The Students

All of our master's students work fulltime in different industries, from small and medium-size software organizations to large IT Departments of non-IT companies such as banks and

government agencies. Most of them are programmers, software developers, software architects, and project managers. A small percentage of our students have other job profiles such as service management and support desk professionals.

2.2. The Teachers

The first author was the instructor of the Software Testing course, while the second author was the instructor of the Software Quality Assurance course. At the time of the study, the former teacher was an Assistant Professor with two years of teaching experience. She has a Ph.D. in Computer Engineering, academic background in software testing, and three years of industry experience as a software tester. The other instructor is a Full Professor with 25 years of teaching experience. He has a Ph.D. in Computer Science, has worked as a consultant establishing Software Quality Assurance systems in software companies, and has taught several seminars on software quality assurance and software project management in different countries.

2.3. The Software Testing Course

The Software Testing course was offered for the first time in 2009 and was taught two times since then by a different teacher (with slightly different objectives and methodology). In Spring of 2011, the course was taught by the first author of this paper, who introduced the learning journal as a way to make the learning process more visible to both students and teacher. There were 14 students registered in the course during that semester. Next we present the general and specific objectives of the course when this study took place.

The main objective of the ST course is to provide students with a practical introduction to software testing processes, techniques, and activities within the context of quality assurance. After completing this course, students will be able to:

- Explain the fundamental concepts of software testing.
- Identify relevant elements and best practices of software quality related to software testing.
- Compare the different software testing techniques, levels, and types.
- Reflect on their learning process.

2.4. The Software Quality Assurance Course

The Software Quality Assurance course has been offered only once in the Spring of 2011. It was taught by the second author, who used a variation of learning journal as a formative assessment tool of students' learning at a couple of milestones during the semester. There were 17 students registered in the course during that semester. Next we present the general and specific objectives of the course.

The main objective of our SQA course is to prepare the student to be able to apply modern tools in the design and implementation of a quality assurance system for the software development process. At the end of the course, students will be able to:

- Identify the main elements associated to the quality of the software process.

- Design and implement components of a quality assurance system for a software development process.
- Apply a clear vision of quality in the various components of the software development process from a practical perspective.
- Perform quality audits of the software development process and technical reviews of software products.

3. METHODOLOGY

We present a case study where two different reflection mechanisms were used in a couple of graduate courses in the area of software engineering. In the Software Testing course a learning journal was used, whereas the Software Quality Assurance course used a two-part reflection questionnaire. Figure 1 illustrates the two different approaches used in each course. Figure 1 shows that there were five interventions in the case of the Software Testing course and two in the case of the Software Quality Assurance course. It also shows that there was a formal Department survey at the end of each course, which was used as an independent assessment instrument for cross-validating some of our findings. The purpose of the implemented reflection methods differs from that of the official Department survey. The Department survey aimed at evaluating both the instructor's performance and the quality of the course, from the students' viewpoint. Meanwhile, the reflection methods served as a tool for students to organize their reflections about their learning, and as a tool for teachers to obtain early feedback about the teaching and learning process. Another way in which the reflection mechanisms differ from the Department survey is in the timing of their application, i.e., the latter one is applied or performed at the end of the course whereas the former ones are applied throughout the course. Nevertheless, we acknowledge that some of the questions asked in the reflection mechanisms are similar to those in the Department survey, and in this regard we view them as complementary assessments.

3.1. Learning Journal in the Software Testing Course

3.1.1. Implementation

The reflection mechanism used in the ST course was a learning journal. Students were asked to write a journal entry every 3 weeks (on average) and there were 5 checkpoints during the semester. This journal accounted for 15% of the final course grade. The style and format were mainly free with the only constraint that the journal had to be electronic and accessible online. Most of the students created a blog for their journals, and all of them made the journal private but shared it with the teacher (it was not open-access and public).

In order to guide students, the teacher gave them four questions to consider when writing their journal entries:

1. What have you learned so far?
2. What activities have helped you to better understand the material (content)?
3. What activities have not helped you to understand the material?
4. What suggestions do you have for future classes?

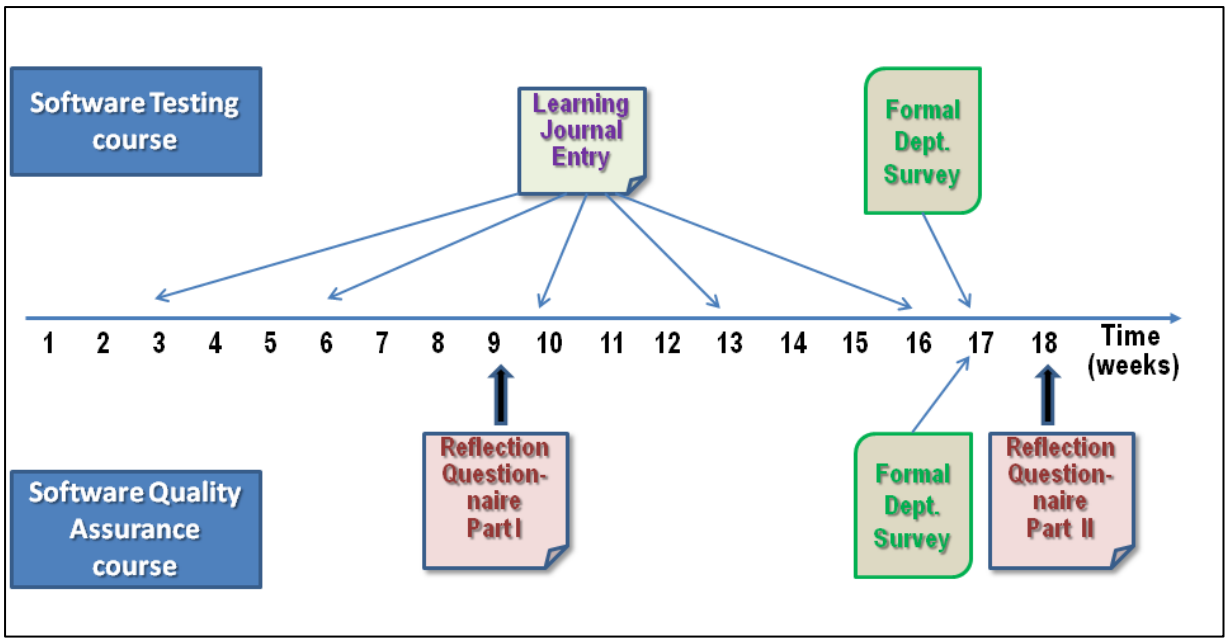

Figure 1. The two different approaches used to implement reflection.

Grading of the student learning journals was done by the teacher, and the feedback was provided either through the blog itself (when the blog website allowed it) or via email. The aspects that were evaluated at each journal checkpoint were:

- Degree to which the student address the guideline questions.
- Degree to which the student reflected about all the material studied in the course (not only a part of it).
- Writing: Was it clear to understand? Were the ideas logically organized? Were there signs of a rushed or careless work? Did the student put an extra effort and time in writing the journal entry (for example, some students looked for additional material about topics they were curious about and linked to it from their journal)?

3.1.2. Assessment

The use of a learning journal was evaluated both from the student's and the teacher's perspective. Student feedback was obtained through an official course survey and an informal course survey. On the other hand, the teacher made a qualitative assessment based on observed strengths and limitations.

The official survey is run by our Master's Program every semester with the intent to evaluate several aspects of the graduate courses taught during that semester. This survey has general questions that apply to all courses. Participation in the survey is anonymous and voluntary. The semester where this study took place, the official survey was conducted between June and July of 2011 and had a total of 10 participants from the ST course.

The informal survey was designed by the teacher specifically for the Software Testing course. Students had to complete this survey as part of their learning journal (filling out the web survey counted as a journal entry) but they were informed that grading of this part

would be based on effort only (regardless of their answers or comments). This survey was conducted in July of 2011 and had a total of 14 participants. Most questions were multiple-choice type but had an additional field where students could write comments (not mandatory).

3.2. Reflection Questionnaire in the Software Quality Assurance Course

3.2.1. Implementation

The reflection mechanism used in the SQA course was a reflection questionnaire. Students were asked to fill a questionnaire twice during the semester, the first one immediately after the first term exam, and the second one at the end of the course. Both questionnaires accounted for 10% of the final grade (5% each one).

The following guidelines were given to students regarding the reflection questionnaire: "The reflection questionnaire will have two deliverables and consists in developing a personal document to document your learning experiences, reflect about them, and self-evaluate using certain parameters."

The first reflection questionnaire had eight open-ended questions that students had to answer, as follows:

1. What have you learned in this course?
2. Has Moodle (course website) been beneficial in the learning process?
3. Do you consider that the textbook is appropriate? Why?
4. Have the written homeworks helped you in the learning process?
5. Have the videos used in class been useful to understand the subject?
6. What did you learn in the first part of the practical project?
7. What would you personally do to improve your learning and get the most out of this course?
8. What did you learn from the first midterm exam?

The second reflection questionnaire was more structured: it had ten multiple-choice questions, each with an optional comments/justification field.

3.2.2. Assessment

Besides our reflection questionnaire, an official standard course survey was conducted at the end of the course (same used for all courses of the Master's Program). This allowed us to compare and contrast some of the answers from the questionnaire and the survey. Out of 17 students in the group, 14 of them filled up the reflection questionnaires and only 11 filled up the final official survey.

4. FINDINGS AND DISCUSSION

4.1. Findings from the Software Testing Course

4.1.1. Students' feedback

Only one question from the 35 contained in the informal survey was directly related to the learning journal. The question was "How suitable did you find the use of a learning journal in the course?" The multiple choice answers were: very suitable, somewhat suitable, somewhat unsuitable, and very unsuitable (besides the optional comments field). Figure 2 summarizes student responses to this question. We observe from Figure 2 that a total of 86% of the students consider that the use of a learning journal was suitable for the course while only a 14% of the students considered that it was unsuitable.

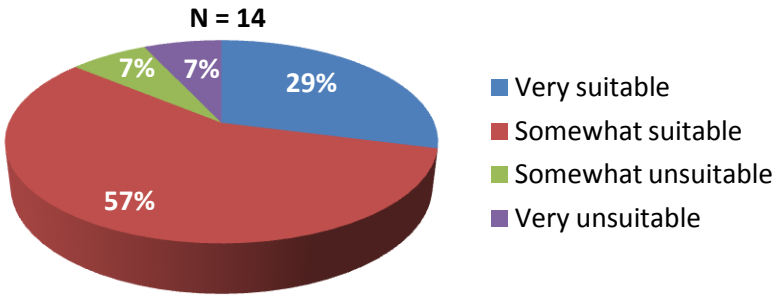

Figure 2. Suitability of learning journal in the course.

Furthermore, for the same question from the informal survey, 12 out of 14 students who completed the survey wrote comments. Table 2 shows all comments from students. We observe from Table 2 that three students failed to see value in the learning journal or were not able to take full advantage of it (see comment from students 8, 11, and 12). This was somewhat expected, especially given the fact that it was the first time they were confronted with writing a learning journal. It is interesting that two students (students 7 and 9) indicated that the journal was somewhat suitable but their comments were rather negative, with a possible explanation being that those students indeed thought that using a journal was suitable but they disagreed with some aspects of the implementation of this journal. Another issue pointed out by two students (students 4 and 6) was that more time should be allowed between journal entries, which we assume was proposed with the intent of allowing students more time to reflect and also more material to think about. On the bright side, two students (students 2 and 5) indicated that the journal helped them to review what they had learned, and two other students (students 1 and 3) conveyed that they liked the journal (one of them pointing out that it allowed him to provide real time feedback on the process).

Table 2. Student comments regarding the suitability of learning journal.

	Answer choice	Comment
Student 1	Very suitable	I liked it, I felt like a writer.
Student 2	Very suitable	It helps to remember what we have learned. It's a constant review.

Student 3	Very suitable	It allows to express views on the process and to provide feedback in real-time, not when the course is over.
Student 4	Very suitable	But I think that the frequency of submission should be every 22 days.
Student 5	Somewhat suitable	It helped a little to review what had been learned.
Student 6	Somewhat suitable	I agree in the idea of having feedback but the intervals should be less.
Student 7	Somewhat suitable	I think it serves more to the teacher than to the student.
Student 8	Somewhat suitable	I think I couldn't fully capture the advantage of the journal; I lacked to connect it to an idea of learning.
Student 9	Somewhat suitable	There was a penalty [in the grade] for not including everything studied in class. Sometimes not everything seemed interesting or memorable. It wasn't nice not to have the freedom to include only what we wanted.
Student 10	Somewhat suitable	It seems to me it is a good tool for expressing doubts about the subject, but I don't see necessary to make comment s on the studied material.
Student 11	Somewhat unsuitable	In my case as a student I didn't really find it useful. I believe that learning can be measured through quizzes and that a learning journal does not say much about what I learned in the course.
Student 12	Very unsuitable	Actually I didn't find any enrichment value. It often demanded much time that one didn't have; besides, it seemed very drastic that failing to submit the journal on the due date deserved a "0". I think that such delays should decrease the grade by a daily percentage, in order to give students the opportunity to submit late if needed, because after all the journal entry would be done after and I think that is what matters for this activity.

Next we will show the more relevant results from the official survey. The course was rated by students with an average grade of 8.5 out of 10 (actual ratings ranged between 7 and 10). The teacher was rated with an average grade of 8.6 out of 10 (actual ratings also ranged between 7 and 10). There were other questions that could be related to some extent to the use of a learning journal in the course, but the relationship is not always direct, therefore we caution that results from these questions cannot be taken as conclusive. Next we present these results.

Figure 3 summarizes student responses to the question "Does the teacher pose activities that allow you to think in a critical, diverse and novel way?" We believe that the learning journal used in the course can be considered an activity that allows students to think critically, since

reflection is an inherent part of critical thinking. It also allows students to think in a novel way because they have to think about what they are learning and how they are learning it (meta-cognition level). We observe from Figure 3 that 50% of the students consider that the teacher poses activities that allow them to think in a critical, diverse and novel way "almost always" or "always".

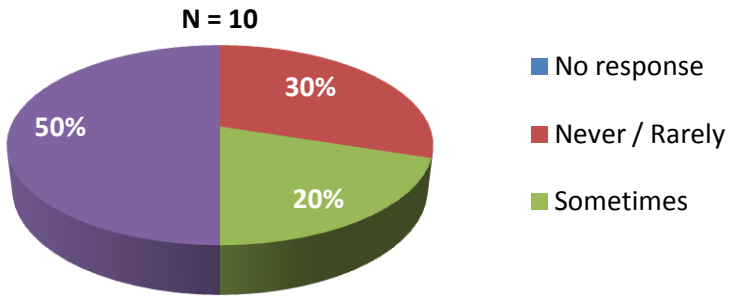

Figure 3. Frequency of activities that allow critical and novel thinking.

Table 3 summarizes student responses to the question "With regard to the course objectives outlined in the program syllabus, you believe that the course met...?" Recall that one of the course objectives was that students be able to reflect on their learning process. We observe from Table 3 that 80% of the students considered that the course objectives have been fulfilled at a level of 60% or more.

Table 3. Degree of fulfillment of course objectives (N=10).

Response categories	Percent of student responses
Less than 25% of the objectives	0%
From 25% to less than 60% of the objectives	0%
From 60% to less than 95% of the objectives	50%
95% or more of the objectives	30%
Do not remember or do not know the course objectives.	20%

4.1.2. Teacher's assessment

The teacher noted that most students were initially very excited and motivated with the idea of writing a learning journal for the course, possibly because it was the first time they were asked to write a journal in a course. However, a few students did not seem too excited about it and expressed concerns about what were they supposed to write and how would it be graded. In order to reduce the anxiety in students, the teacher discussed with them the purpose and benefits of the using a learning journal in the course.

Some of common tendencies found in the first journal entries were: (*i*) summarizing the material studied in class with little or no reflection about the learning process, (*ii*) writing only about the part of the material that they found most interesting, (*iii*) very brief writing. These

issues were addressed through formative assessment besides the summative grade associated to each checkpoint.

Formative assessment was provided to students individually after each journal checkpoint, identifying strong and weak points in their work. This feedback was normally in the form of an email, although sometimes comments were left in the blog itself. The following are sample feedback sent to students by the teacher:

> "Your journal entry is fairly complete. I liked that you related what you have learned in the course to your professional practice. I hope you keep making this link in future entries of the journal."

> "I really liked your journal entry, especially the analysis you made of the teaching methodology of the course, since it gives me clues as to what things I'm doing right or wrong as a teacher. The level of technical detail used for the analysis of what was learned was also appropriate."

> "I really liked your journal blog, especially the links you included. The only observation I have is that you neglected the 'form', i.e. you have some typos and other writing errors, which gives the impression of a rushed work. For the future checkpoints, try to be more careful with grammar and spelling details so that the work has a higher quality."

> "Your journal entry is okay but somewhat short; I feel you could have expanded your reflection on what you have learned (what did you get from the topics studied, how did you connect/relate the different topics studied, more details about what you found most interesting or more contradictory with respect to preconceived ideas, etc). In general it is easier for me to assess the learning process when students express their ideas in more detail."

> "Your journal entry was very original, as usual. I liked the video about Unit testing and TDD. I also found very helpful the other video on Coded UI tests. I have only one observation: you did not mention anything about the test plan documentation, which was a topic extensively studied in class, and I would have liked to know what you learned on that dimension."

In three of the five journal checkpoints, two students failed to submit the journal entry on time, resulting in a grade of zero for those students. Only one student failed to write a journal entry twice during the course, the other students failed to submit the journal entry only once in the semester. Additionally, journal grades were reasonably good overall, as can be observed from Table 4. This table shows the average and standard deviation of grades obtained by students at every journal checkpoint. Note that the standard deviation at checkpoints 1, 3, and 4 was considerably larger than at checkpoints 2 and 5, which is attributable to the fact that those where the checkpoints where two students obtained a zero. Note also that all students obtained the maximum possible grade (100) in the last journal checkpoint, because this checkpoint corresponded to completing the survey prepared by the teacher and students were given full credit if they completed it and made comments in some of the ques-

tions. The teacher believes that all these are indicators of a successful experience since it shows that most students were making the effort and putting the time in writing good journal entries and meeting the purpose of reflecting about their learning process.

Table 4. Grade statistics for the journal checkpoints.

Journal checkpoint	Average	Std. dev.
Checkpoint 1	82.9	35.2
Checkpoint 2	94.3	8.5
Checkpoint 3	82.5	35.2
Checkpoint 4	81.4	35.0
Checkpoint 5	100.0	0.0

As it was mentioned in the Introduction, one of the motivations for introducing reflection mechanisms in our courses was that we wanted students to achieve a deeper and more enduring learning from the course. Being able to measure the degree to which this aim was attained is, however, a difficult task. One way in which this could be evaluated is surveying students a year (or so) after the course has ended, on the use of reflection and also on key concepts of the material studied in the course that we would expect them to have learned deeply. Unfortunately, we haven't done this yet but it is an idea that we would like to pursue in the near future.

A major drawback of learning journals was the burden posed by grading since it is very time-consuming to read over every journal entry (some of them were rather large) and provide individual feedback to students. Hence, we believe that this reflection mechanism does not scale up well for large classes (unless you want to leave the grading to the Teaching Assistants).

4.2. Findings from the Software Quality Assurance Course

4.2.1. Students' feedback

Some of the answers from the official survey were quite surprising for us as instructors. For example, Figure 4 shows students' answers to the question "Do you duly read the required material?" Less than a third of the students actually read the material consistently in advance.

On the other hand, Figure 5 shows the way students see their own preparation for the course exams, in response to the question "Do you prepare adequately for the course evaluations?" The answers for this question were significantly better than for the previous one, with 45% of the students saying they "always" or "almost always" prepare adequately for the exams.

Of most concern for us is the lack of in-class participation from some students, as shown in Figure 6. This chart summarizes students' answers to the question "Do you participate, raise questions and make comments in class?" A total of 54% of students said they "never" or "almost never" participate with questions or comments during class. Actually, this question

originated comments in the survey such as “the teacher should encourage more student participation during class” and “the teacher should make classes more participatory”, underlining the need for more in-class involvement by the students.

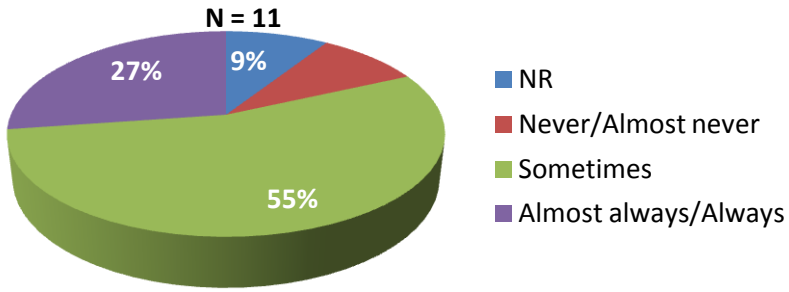

Figure 4. Students’ assessment of their own preparation for class.

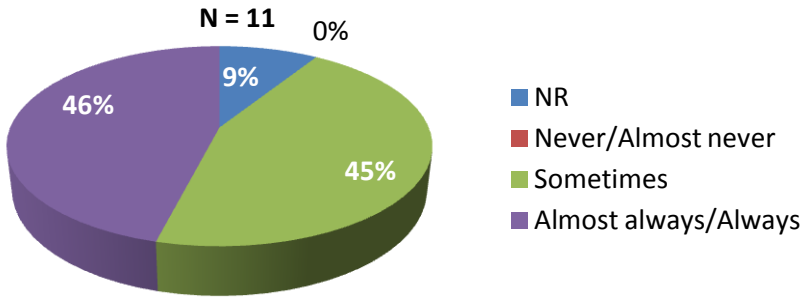

Figure 5. Students’ assessment of their own preparation for exams.

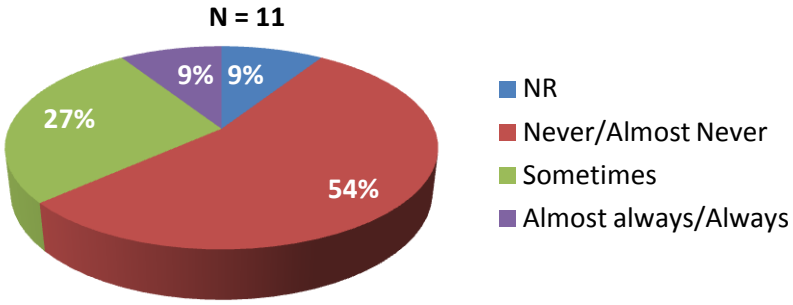

Figure 6. Students’ participation in class.

Some of our findings from students’ reflection questionnaire were that students needed more in-class hands-on exercises to grasp the concepts, and that most of their learning was not done in class but during the development of the term project.

Finally, Table 5 shows the results from the official survey about how the students rated three important characteristics of the course in a 0 to 10 discrete scale. In average, they assigned a grade of 8.7 to the overall course, and a grade of 8.9 to the overall teacher´s performance, which are both considered good ratings. Interestingly, they rated their own performance as students in the course with an average grade of 8.5, meaning that they believe there is room for improvement in the performance of some academic activities related to this course.

Table 5. Students' opinion about overall aspects of the course (N=11).

Question	Average	Std. dev.
Overall course quality	8.7	1.45
Overall teacher performance	8.9	1.97
Overall student self performance	8.5	1.85

Regarding the students' own interpretation of their course performance, the reflection questionnaire had a question asking "What could you personally do to enhance your learning". The three common answers we received were: attend more classes, doing the pre-class reading more often, and having the opportunity to do more hand-on exercises during class. We will surely take these observations into account next time we offer this course.

4.2.2. Teacher's assessment

By the end of the course, we had asked the students to fill up three questionnaires, as shown in Table 6.

Table 6. The three questionnaires used in the course.

Questionnaire	No. of students who responded (N)	Type	Structure of the questionnaire	When was applied
Reflection questionnaire Part I	17	Not-anonymous	8 open-ended questions	Midterm
Reflection questionnaire Part II	14	Not-anonymous	10 multiple-choice questions with optional comments field	End of term
Official course evaluation survey	11	Anonymous	40+ multiple choice questions with optional comments field	End of term

The main shortcoming of the reflection questionnaires is that except for the grade, no individual formative feedback was given to the students. However, its strength is that, despite not being anonymous, they allowed our students to be truthful and forthcoming expressing their opinions and ideas, and they did hold back anything about the different aspects of the course and the teacher. Furthermore, the reflection questionnaires, used for the first time by most of the students, forced them to think about how they learned in the course, making the experience more fruitful.

5. Conclusion and Future Work

We presented two examples of reflection mechanisms used in software engineering graduate-level courses. In particular, our case study included the use of a learning journal in the Software Testing course and a reflection questionnaire in the Software Quality Assurance course, both part of the Master of Science Program in Computer and Information Science.

Based on our experience, we conclude that grading was a difficult task in both courses partly due to our lack of familiarity with assessment of reflective writing (it was our first time implementing reflection). Grading was particularly time consuming for learning journals where individual feedback was given to students on a regular basis (after each of the five checkpoints). On the other hand, we believe that students benefit more from constant or regular reflection such as writing journal entries than from reflecting twice in the semester as in the case of the reflection questionnaires. However, we still need to explore what is the best time interval between reflections for our courses since some students under the journal mode pointed out that more time between journal entries was needed. The benefit on the teacher's side does not change as much if the main objective is to obtain feedback from students regarding specific aspects of the course, but if the main objective is to evaluate the progress in students' learning process, then it is advantageous to have more samples along that process. We also believe that when the teacher seeks truthful feedback, assessment and comments from students regarding the course (and the teacher), the best way to obtain it is ensuring that students' answers are anonymous and hence not graded (otherwise answers might be biased or misleading). However, other types of reflection that require a significant effort on the student's side would need to be graded in order to motivate students to do a high quality work.

Among the lessons learned from our experience, we recommend that the reflection questionnaires be continuously revised and improved, experimenting with different types of questions depending on whether they are anonymous or not. Our study used graded non-anonymous questionnaires, but it is clear to us that both options (anonymous and non-anonymous) have advantages and disadvantages, and that the choice made imposes restrictions on the kind of questions that can be asked to the students. In the future we would like to experiment with both anonymous and non-anonymous reflections in the same course, always having the official Department survey as a complementary assessment method.

Another lesson learned is that before using a reflection mechanism, instructors need to have clarity about what its main purpose is (e.g., formative, summative, or both) and who are the principal users (the Department, the students, or the instructors) in order to choose suitable types of questions and the most suitable method of carrying it out (anonymously or non-anonymously).

Our students are just starting using reflection to enhance their learning, thus, some of them do not fully appreciate its value yet. We as instructors must do a better job at explaining it at the start of the course by showing them the benefits of reflection using examples and case studies from previous courses.

The instructors are both satisfied with the initial results and plan to continue its use in the near future. To do that, we plan to explore how to merge the two approaches explained in this paper and obtain one combined method of reflection to be applied consistently in several graduate level courses, in such a way that the students themselves would learn to appreciate its value too. This would also entail the development of a rubric for grading students' reflective writing in a more consistent and objective way, as well as the definition of clear and realistic learning/teaching outcomes from the reflection mechanism used (for example, a compromise is needed between teacher's and students' benefits and investments).

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