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Application of Peer Review Techniques in Engineering Education*

MIGUEL Á. CONDE, LIDIA SÁNCHEZ-GONZÁLEZ, VICENTE MATELLÁN-OLIVERA and FRANCISCO J. RODRÍGUEZ-LERA
Department of Mechanics, Computer Science and Aerospace Engineering. University of Leon, León, Spain.
E-mail: miguel.conde@unileon.es, lidia.sanchez@unileon.es, vicente.matellan@unileon.es, fjrodl@unileon.es

Improving students' involvement in universities classes is a challenging problem. This problem is particularly relevant in technical studies, even worst in computer related subjects where students tend to be very independent. In this paper, we propose the use of peer review as a methodology that can help students to get more involved and to develop specific abilities has critical thinking. We have successfully used this approach in three different courses in different years (freshman and sophomore) and different studies. Quantitative and qualitative data was collected during these experiences to evaluate students' opinion and performance. This information is analysed and discussed in the paper and our conclusions are also highlighted as well as some ideas for future improvement.

Keywords: peer review; technical studies; evaluation; workshop

1. Introduction

Teaching and learning are processes that should evolve to address students' needs and institutions requirements, taking into account the sociocultural context of educational stakeholders. In this sense, students of technical disciplines (i.e. mechanics, electrical and electronical engineering, computer science, architecture, statistics, etc.) must acquire practical competences that in most cases have to be assessed through practical assignments or the development of projects.

The classic classroom model has been changed in the EU by the Bologna Process [1] and the participation of students is essential not only during face-to-face sessions, but in the evaluation process. A possible way to achieve this is by applying peer review techniques to the practical assignments or the projects above mentioned.

Peer review is not something new. It has been used for decades in very different disciplines such as Architecture, Music or Computer Science. Peer review is associated to collaborative learning because it requires that students assess their peers' work and also provide them with feedback [2–4]. Effective feedback can increase students' motivation, change their behaviour and improve their learning [5–7].

However, peer review application means a change in the traditional evaluation model. The responsibility of the evaluation is not a sole responsibility of the tutor, students have a more active role, managing their own learning [8] and participating on it [9].

Peer review is one of the ways to do this [10]. There are other evaluation techniques that share similar benefits [2]:

- Different points of view. Students are exposed to a greater diversity of perspectives than just those from their lecturer. Feedback from their peers makes them think over their work and how to improve it.
- Involvement in the evaluation process. Students participating in the evaluation process should be careful with the feedback and grades they are granting to their peers. For instance, students should adapt their writing style to be clear, should expose properly their ideas, and highlight the advantages and disadvantages of their peer solutions.
- Building problem solving skills. Critical reading of others' work helps students to identify areas needing improvement and to prove constructive suggestions.
- Increasing student motivation. Participation in the evaluation process fosters a sense of responsibility and ownership on their peers' learning.
- Promoting independent learning. Peer review reduces dependence on 'the experts', something that could be useful in other learning contexts and in the workplace.

Peer review techniques are very popular and have been applied in different contexts. Just to mention some of them, we can mention its use in the History of Art at the Utrech Universtiy [11], in technological studies [12, 13], in Education [14] or in even in High Schools [15]. Several approaches [14, 16] have assessed the outcomes of these experiments and the stakeholders' perception.

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Present work aims to present how peer review has been applied in different technological courses at the University of León (Spain). This work explores its use in an Operative Systems course taught in the second year of the BSc in Computer Science; in the Informatics course in the first year of Industrial Electronics Engineering and in the Informatics course also offered in the first year of the Mechanical Engineering.

In order to describe these experiences the paper is structured as follows. The following section presents the context of the research. Section 3 shows how peer review was applied and how it was evaluated. In Section 4 results are described and finally some conclusions are posed.

2. Research context

This work was developed at the School of Industrial and Computing Engineering of the University of León (Spain). This School has about 2,100 students in technological majors such as Computing Engineering, Mechanical Engineering, Industrial Electronics and Automation Engineering, Electric Engineering and Aerospace Engineering. The Schools also offers Masters, a PhD program and specific courses for graduate students.

Practical assignments are based on the delivery of work and/or practices in the School. As previously mentioned, three courses have been chosen for this study. The evaluation of these subjects is based on the development of programs written in C language by the students to solve a problem proposed by the lecturers. Students must present their solutions to the lecturer, as well as answer questions about their work to ensure its originality and the comprehension of the work done. The lecturer assigns the grades according to the quality of the solution and the answers to the quizzes.

Previous experience of the authors in these subjects courses shows that: (1) Students present difficulties to solve the problems proposed because of the lack of knowledge in programming; (2) Students do not elaborate the same kind of solutions; (3) Students find it difficult to understand the grades that the lecturers award to their assignments; and (4) In many cases, students might crash during the defence and their grades might be reduced or not even pass the subject.

In order to solve these problems and to increase the critical capacity of the students, the proposal of this work is that one of the assignments is assessed using a peer review technique. Students anonymously view the work of colleagues and observe different solutions and they also assess these solutions. Furthermore, such assessment will be taken into account for both the final grade of their own practice and of their class mates ones. This implies that students learn more about C programming or Operating Systems since they must consider the algorithms designed by the other students; they also develop their critical thinking because they have to assess the work developed by the rest of the group; and have to compare these solutions with their own works. This offline peer evaluation also solves a recurrent problem in these assignments that students showed during in-person presentation of their works in front of the lecturers. They got very nervous and anxious. It must be noticed that this activity helps in the acquisition of core competences specified in the syllabus of the subjects. Besides this, practices have been also corrected by the lecturers and the grade given by the students has been compared to the one assessed by the lecturers, computing the final mark as the weighted mean of all the grades as described in the following section.

In the following sections the rest of the article presents the results of applying the methodology to the above-mentioned subjects.

3. The experiment

In order to show how peer review is applied, this section describes the courses, how it is applied, and how the application of the methodology is evaluated.

3.1 Operating systems (OS)

OS course deals with the fundamentals of how an operating system works. It had 114 students in the year 2013/14 that were the sample used in this experience. This is a practical subject in which most of the lessons implies lab work by carrying out activities related to how to manage and program an operating system. This lab work is complemented with some lecturing where theoretical fundamentals are presented. Subject assessment comprises several questionnaires about the theoretical/practical concepts (35% of the final grade) and two practical assignments (65% of the final grade). The first assignment (Intermediate Assignment) accounts for a 35% of the final grade and the second one accounts for the rest (Final Assignment). The lecturer evaluates these assignments and the students must present and defend their solutions in person.

3.2 Informatics for Industrial Electronics (IIE)

IIE subject teaches students the fundamentals of computer programs and tries to develop the ability to build small programs in a compiled programming language. The programming language used was C. The subject had 84 students in the year 2013/2014. IIE is also essentially a practical subject, where

lecture sessions are combined with lab work. The subject assessment was similar to the one described for OS. It comprises several questionnaires to assess theoretical/practical concepts (30% of the final grade) and two practical assignments (70 % of the final grade). This 70% was divided in two assignments, the intermediate with a weight of the 35% over the 70% and a final one weighted with a 65% over that 70%. Teachers evaluate these assignments and the students must present and defend their solutions.

3.3 Informatics for Mechanical Engineering (IME)

IME is aimed at how to develop programs using the C language. In the year of the experience, 2013/14, the number of students, and therefore the sample size, was 123. This subject is also completely practical. Lecturing covers the fundamentals on how a computer works, programming fundamentals combining theoretical principles with practical examples. Such topics are deeply faced in the lab where students must solve different common problems firstly by designing algorithms and later writing them in the C language. The assessment of the subject is as follows: (1) An assignment in which students have to design several algorithms to solve certain problems (10% of the final grade); (2) An assignment in which students have to develop a program in C (20% of the final grade); (3) An exam using the computer where the students have to write a C program in order to solve a given problem (60% of the final grade); (4) A short answers questionnaire about basic concepts of computers (5% of the final grade); (5) A short answers questionnaire about the use of basic shell commands in a GNU/Linux system (5% of the final grade).

3.4 Application of the peer review assignment

The application of the peer review assessment is carried out in the first of the two practical assignments that the students must hand in OS and IIE, which were called Intermediate assignments. In IME, the methodology is applied to the algorithm designing.

Peer review methodology follows the following steps in the three cases:

1. Lecturing the required knowledge to develop the assignments. For instance, it comprises concepts of POSIX operating systems, C programming syntax, etc. Students need this knowledge to carry out the assignments, in other words, all these concepts are handled during the lab work.
2. Learning to use the peer review tool. Students are taught how to use the tool to peer review their classmates' works and which critical aspects must be taken into account when assessing them.
3. Peer reviewing. Students submit an assignment and anonymously 3 different classmates are assigned to evaluate it. They review it according to specified criteria and always providing a feedback to the author. The lecturer assesses all the assignments following the same criteria and including also comments. This mechanism is used in the three subjects but how the final grades are awarded is different:
   - For OS and IIE, the final grade is calculated as weighted combination of the grade given by the lecturer (70%), the peers' evaluation (20%) and the quality of the evaluations graded by the student (10%). The last one is computed as a function of the standard deviation of the evaluations that have been carried out.
   - For IME, the 70% of the assessment is obtained as the average of the evaluation of the lecturer and the evaluation of the peers. The remaining 30% corresponds to the quality of the evaluations carried out by a student.
   - In order to provide guidance for peers' assessment and to guarantee some homogeneity some criteria are given by the lecturer. In OS and IIE students should attend to practice performance (the program should work properly), correctness-code quality (issues related to how readable code is, if it is well indented, efficiency, etc.) and solution quality (if the solution could be improved). In IME, lecturers provide students with a specific rubric for the assignment. It explores several matters to consider: formal aspects (if the structures were well used) and functional aspects (if the algorithms were appropriate to solve the proposed problems).
4. Assessment of experience. A mixed methodology has been followed to evaluate the results of the experience that considers quantitative and qualitative results. It will be described in the following sections.

Researchers and lecturers in the different courses agree to use Moodle Workshop for this experiment. Moodle was also being used in the subjects to support lectures and lab work, so It would be easier for the students to use a tool included in their LMS, they have not to change their learning context. Moodle workshop has been configured (Fig. 1) in order to allow students delivering an assignment and assessing anonymously another

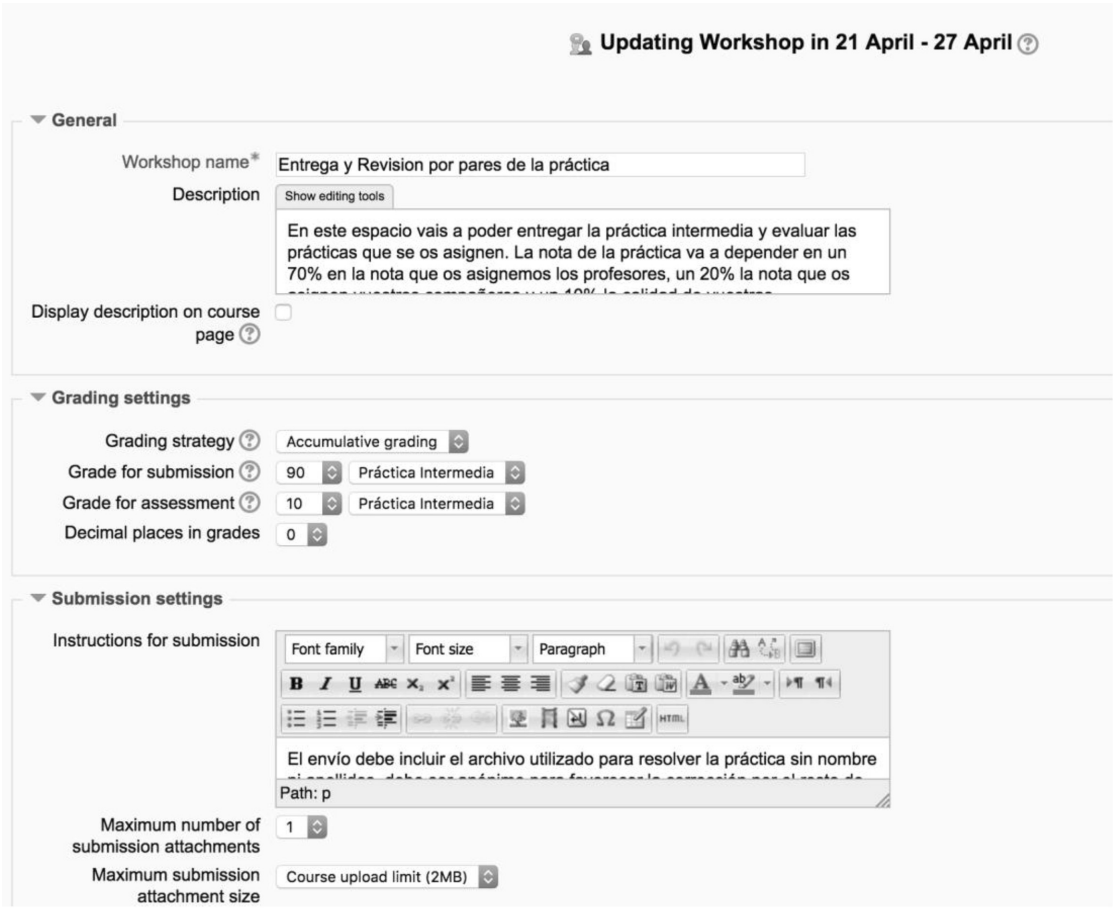

Fig. 1. Workshop configuration option panel.

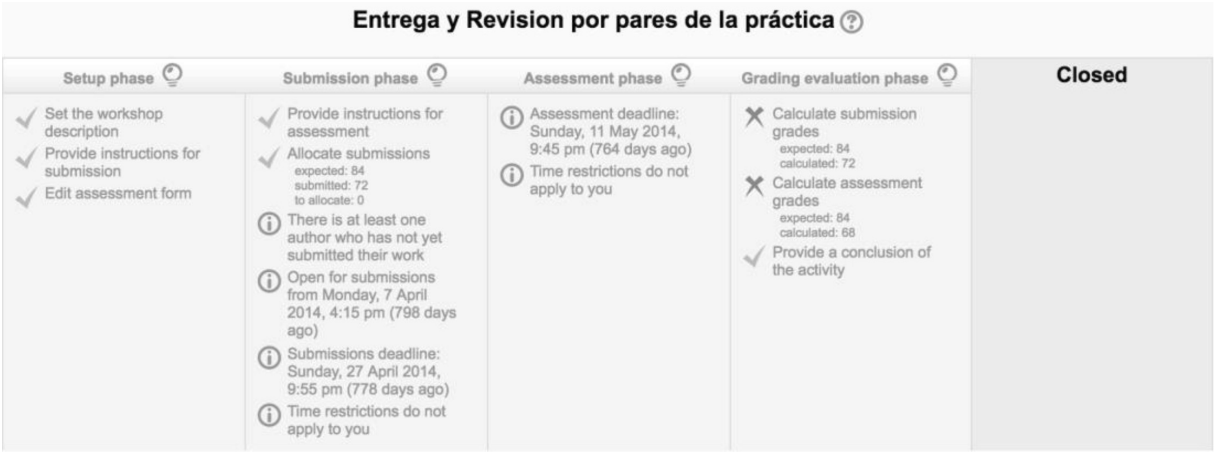

Fig. 2. Workshop tracking panel.

three. Comments are set as mandatory in this configuration and the module also provides control about delivery and assessment dates. Moreover, the tool can be configured to include fields for the assessment form that takes into account both the criteria provided in OS and IIE, or the IME rubric.

The Workshop Tool also makes possible to control different stages of the peer review activity (configuration, delivery, assessment, grading, closing)—(Fig. 2). It also shows the results of each student and the grade given by their classmates, being possible for the lecturer to analyse the grades in case it was required.

GoogleDocs has also been used to provide a questionnaire to assess the satisfaction of the students. It is described in the following section.

3.5 Methodology to assess the application of peer review

Two strategies are considered to analyse this experience. First, quantitative data from the current experience is compared with previous years results. Next, a satisfaction questionnaire that collects numerical data and raises open questions is carried out. A mixed methodology was chosen to analyse data both quantitative and qualitative [17].

Several significant values are computed for the quantitative analysis: the average of the grades given, deviations in the assessment of peers assignments, percentage of students that deliver the assignment, and the time they spent to do it. Such values are compared (to the extend possible) with those obtained in previous years.

More quantitative data is obtained through a user satisfaction questionnaire filled by the students regarding the practice. This questionnaire is based on the adaptation of the one used in the work by Xiao y Lucking [14] to measure the satisfaction in peer review activities. Specifically, this questionnaire attempts to assess both the student satisfaction with the tool (the Moodle Workshop activity that is used to carry out the peer review) and with the assessment method, that is, the use of peer review vs. other evaluation methods. It includes 20 questions based on a 4 value Likert scale (Strongly disagree, Disagree, Agree or Strongly Agree). Two additional items were also included to collect the number of hours that students spent to develop the assignment and to review the three peers' works assigned to each of them.

Table 2 shows the items of this satisfaction questionnaire and also can be checked in https://docs.google.com/forms/d/11alihmtO14AQCN93NTqAKhKatmoQepCtwmy97zyXGM/viewform.

This questionnaire raises some open questions that ask students about their opinion on the tool and the assessment method. The obtained answers are evaluated qualitatively, which means several thematic categories are defined and subsequently the results are summarized according to these categories. [18].

Table 1. Quantitative information about the subjects, including number of students in 2013/14 academic years, how many of them completed the assignment that year and the previous one and information related to the assignment students grades

Subject	Students	Participants (13/14)	Participants (12/13)	Deviation from teachers grade	Av. grade assignment (13/14)	Av. Grade assignment (12/13)
OS	114	88/114 (77.19%)	65/94 (69.14%)	6.7/100	68/100	39.68/100
IIE	123	70/84 (83.33%)	68/94 (72.34%)	4.7/100	49.6/100	41.2/100
IME	84	109/123 (88.61%)	107/122 (87.7%)	11.5/100	47.43/100	46.1/100

Table 2. Satisfaction questionnaire about peer review use

Assessment Items employed	Av. OS	Av. IIE	Av. IME
Satisfaction with the assessment system			
I1. The peer feedback/rating system is appropriate for the assignment evaluation	3.16	2.68	3.25
I2. The peer feedback/rating system included into Agora makes me feel comfortable	3.36	2.94	3.25
I3. The peer feedback/rating system was too demanding	1.72	2.12	2
I4. The peer feedback/rating system made me feel responsible for my own learning and for others learning	3.01	2.96	3
I5. It is easy for me to complete my feedback/rating assignments	3.14	2.81	3
I6. The use of the tool used for doing peer assessment is efficient with regard to the other tools included into Agora	3.18	2.91	3
I7. I feel confident in my ability to evaluate others' work during the peer feedback/rating activities	3.27	2.81	3.25
I8. The tool used for doing peer assessment allows me to rate and provide feedback to my peers' works quickly	3.27	2.96	3
Satisfaction with peer feedback			
I9. I enjoy giving peer feedback	3.01	2.62	2.65
I10. I enjoy receiving peer feedback	2.89	2.75	2.65
I11. I believe that it is important for me to learn how to give feedback and how to use that provided by my peers	3.16	3	2.75
I12. Giving feedback is an effective approach to improve my critical thinking skills	3.43	3.06	3
I13. Taking feedback is an effective approach to improve my critical thinking skills	3.14	2.82	2.7
I14. I'm satisfied with the overall quality of the feedback I've received	2.61	2.46	2.45
I15. I'm satisfied with the overall quality of the feedback I've given	3.21	3.03	2.9
I16. The peer feedback I received was helpful to improve my work	2.96	2.75	2.65
I17. Peers have adequate knowledge to evaluate my work	2.50	2.37	2.45
I18. I have benefited from rating my peers' works	3.30	2.89	2.95
I19. I think I have learned more from peers' feedback than from the instructors' feedback	1.89	2.25	1.25
I20. I felt reluctant to give negative feedback to my classmates	2.18	2.64	2.5

4. Results

The experiment, as commented above, involves 3 subjects with a total of 322 students, although not all the students delivered their assignments (because it is not a mandatory activity). Table 1 shows the distribution of the students, their participation, the deviation of students grade for each work compared with teachers grade, the average grade for the assignment in the academic year 2013/14 and the comparison with the previous year.

The number of hours employed to develop the assignment is also gathered by the questionnaire. However, there is not information about this issue in previous editions of the subjects; so, it is not possible to compare the results with previous data and the information is not included into the table.

The quantitative data about students' perception about peer review are shown in Table 2. This table is divided in two parts. The first one describes the satisfaction of students with Moodle Workshop activity, that is, with the tool used to carry out the peer review experiment. The average grade given by the students of each subject to each item is shown in the table columns. The second part of the table is structured in a similar way but it includes information about the satisfaction of students with their peer assessment.

In addition to the items of Table 2, the questionnaire includes two voluntary open questions. One was referred to the satisfaction with the tool while the other regards to the methodology. The results for these open questions were also evaluated. There were answers from 8 students from OS, 7 from IIE, and 0 from IME. In order to analyse these comments, a qualitative technique is used and several thematic categories were defined. These categories were the system and tool employed, and the evaluation methodology. Table 3 summarizes the results according to this classification.

5. Discussion

From the information gathered in the experiment it is possible to see that the participation is higher than the 65% of the enrolled students in all cases, and that it grows up every academic year. We think that this increment is caused by students new role, that is, we think that peer review motivates the students by making them take part on the evaluation process, which also leads to better grades [19, 20] as those shown in Table 1, obtained after peer review application. As this assessment can be constrained by how brilliant are the students of the subject for this academic year, it would be interesting to compare the results with more editions of the same subject.

It is also interesting to study the deviation between the grades student award to their assigned works and teachers' grades for the same works. In Table 1 it is possible to see that this deviation goes between 4.7 and 11.5 points over 100 in any of the subjects. In order to assure the validity of students score [14] Pearson product-moment correlation analysis was used, resulting in a $r = 0.971$, indicating that the relationship between student rating scores and instructor grading scores is significantly and strongly correlated. There are not specific works that explore peer review in practical assignments of technical degrees, but this proximity between students' and instructors' scores is similar to the observed in other applications of peer review [15, 21–24].

Regarding the assessment of the peer review system and the tool employed, satisfaction is high for the students of OS and IME (with values higher than 3 = Agree) and the results were not so high, but near to 3, for the students of IIE. Students found the use of the system and the tool straightforward and think that it does not require much effort. Good results regarding the system used were obtained in other works that employ a similar research instru-

Table 3. Qualitative Analysis Results

	Peer review system and tool	Evaluation
Student OS 1	-	Low grades in propose
Student OS 2	To see other reviewers answers	–
Student OS 3	–	Lower grades from my peers than from the teacher
Student OS 4	–	Useful but problems with my peers knowledge
Student OS 5	–	The more we use it the higher motivation
Student OS 6	–	Problems with peers feedback
Student OS 7	Use it in non–evaluable assignments	
Student OS 8	Efficient it helps to see other solutions	Hard to be responsible of other grades
Student IIE 1	–	I feel bad evaluating other peers
Student IIE 2	Clear and objective evaluation criteria	Some peers do not know what to evaluate
Student IIE 3	–	I would change evaluation criteria
Student IIE 4	–	Feedback provided is not good
Student IIE 5	–	Let me learn from others solutions
Student IIE 6	Good System	Not enough knowledge to evaluate others work
Student IIE 7	–	More feedback from teachers and less from peers

ment but a different peer review tool [14]. This might suggest that the tool is not the most important issue for the application of the methodology.

The most significant difference among the students from the different subjects according to our experiments was found in item 1. It asked the students whether peer feedback/rating system was appropriate for the assignment evaluation. The answer by the students from IIE was half a point lower than the one from OS students. This can be caused by the fact that they have never been involved in the evaluation process before and they don't know if the tools were appropriate or not. It should be noted that IIE is a first year subject. This assertion would be later supported by the analysis of the open questions asked to students.

Results for items 9, 11, 12 and 13 have got a grade higher than 3, which means that peer review process was valued as satisfactory by the students. They think that the acquisition of critical thinking in the field of the subject by students. The satisfaction results with the peer review process are consistent with previous works [13, 14, 25] and the acquisition of critical thinking fits with Toppings theories [22] and with Xiao experiments [14].

Despite this fact, students do not consider that their peers have enough knowledge to evaluate their works in an objective way. Values are not very high regarding the feedback and comments received, as can be observed in results for items 10, 14, 17 and 19. That is, for them peer review was positive and they feel comfortable doing reviews and providing feedback, but they were not so happy with the received comments. This is supported by the opinions gathered through the open questions. The reasons for this can be that students are using a new methodology in which their grades depend not only on their teachers but on their peers, and they think that their peers are not ready to assess their works. However, as shown above, they think they are ready to give feedback to their peers, and the validity of the grades and feedback given is very close to teachers' grades according to our analysis.

From the qualitative analysis, it is possible to see a positive perception about the tool and the peer review system, specially because it allows to see others solution, although it could be improved if other reviewers' feedback would be available when they are evaluating. This analysis also explores the students' perception about the evaluation and the results were similar to the obtained in from the quantitative data. Students from both subjects are worried about the knowledge of their peers to assess their own works, and some of them are not happy to evaluate their peers' work. In order to solve this in future experiments it would be positive to show students that in previous applications of the methodology there was a high correlation between the grades that students give to their peers and those given by teachers.

The research developed presents several limitations. The first one was that it would be interesting to compare the results with more editions of the subjects and with other subjects of different universities looking for differences between the different sources. Moreover it would be interesting to redefine the methodology for peer review feedback to be used to improve the work carried out, so not only validity of scores but also reliability could be taken into account [26]. It would be also interesting to support the conclusions obtained from the qualitative analysis with a students focus group [27, 28] and to study the metrics that allow the evaluation of peer review techniques application independently of the application context.

6. Conclusions

Nowadays it is essential that students do not only acquire a basic knowledge about some topics, but also, they should develop critical thinking skills that allow them to apply this knowledge to solve problems. In order to achieve this, students should be part of their own learning evaluation. They should understand that a problem/project can be solved in different ways which means that their solution should always not be the best or the only one. The development of these critical thinking skills can be achieved by the application of peer review techniques in students learning programs. In this way students will be involved in the assessment process, and they will learn from other solutions and with their peers' feedback.

This work describes the application of peer review techniques in different subjects of the University of León and how this methodology is evaluated from a quantitative and qualitative perspective. Specifically, peer review was applied in 3 subjects of technical degrees by using Moodle Workshop tool. It involved 321 students, that should carry out their assignments and evaluate 3 of their peers' works. The results obtained were gathered and analysed.

After the experiment, it was possible to see that the application of this assessment methodology had associated an increase in students' participation, which can be related to the fact that their motivation was increased by the possibility to take part in the evaluation process. Moreover, the grades were better than in previous editions and it was possible to show that, for the experiment developed, there is a correlation between the students' grades given to their assigned works and teachers' grades for these works

Regarding the tool, students think that Moodle Workshop was a proper tool in order to develop peer review activities. The perception of the methodology was also satisfactory. Students see the possibility to access to other possible solutions to problems as something useful, and feel good giving and taking feedback to/from their peers, which contributes to develop their critical thinking. However, they were worried because their peers were not ready to evaluate their own works and this can affect the final grade obtained in the assignment. In order to solve this in future experiments it would be positive to show students that in previous applications of the methodology there was a high correlation between the grades that students give to their peers and those given by teachers.

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Miguel Ángel Conde holds a PhD in Computer Science (2012, University of Salamanca). From 2002 to 2004 he was working in educational environment teaching in several courses related to computers. In 2004 he decided to begin working on software development environments and he worked for GPM, a web development and multimedia company. In 2005 he began working for Clay Formación Internacional R&D department where he was involved in different eLearning projects. From 2010 to 2012 he was researching at the University of Salamanca and also working there as a teacher. During 2013 he worked in the Informatics and Communications Service of the University of León and as assistant lecturer in that university. Now he works as an assistant professor at the University of León. He is a member of the Robotics research group of the University of León and GRIAL research group of the University of Salamanca. His PhD thesis is focused on the merging of informal, non-formal and formal environments. He has published more than 100 papers about different topics such as eLearning, Service Oriented Architectures, Learning Analytics, Mobile Learning, Human-Computer Interaction, Educational Robotics, etc.

Lidia Sánchez was born in León (Spain) in 1980. She got the Computing Engineering degree from the University of León (Spain) in 2002, and the PhD from the University of León in 2007. Since 2003, she has been working at the University of León (Spain) as a Lecturer in the area of Computer Architecture and Technology in the Department of Mechanical, Computing and Aerospace Engineerings. Her research interests focus on digital image processing and analysis applied to medical images and industrial processes. She is also interested in high performance computing.

Vicente Matellán Olivera got his MSc degree on computer engineering and his PhD from the Universidad Politécnica de Madrid (Spain). He was a lecturer at Universidad Carlos III de Madrid (Spain) from 1993 till 1999 and assistant professor at Rey Juan Carlos (Móstoles, Spain) from 1999 till 2008. Since then, he has been an associate professor at Universidad de León (Spain) where he established the robotics group. He is a member of IEEE Technical Committee on Software Engineering for Robotics, editor of the Journal of Physical Agents (http://jopha.net), is leading the Spanish National network on Physical Agents, and is also involved in several research projects. He has published over 150 papers in journals, books, and conferences mainly in the robotics field.

Francisco J. Rodríguez Lera got his PhD in Intelligent Systems in Engineering at the University of León in 2015. Since 2008 he is working in different educational environments from primary school to Master Degree courses always related with programming, operative systems and computer architectures. He is a member of the Robotics research group of the University of León since 2009 and his main research interests include human-robot interaction, verbal and non-verbal dialogue systems, augmented reality, context awareness and robotic software architectures.