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Results of a Peer Review Activity Carried out Alternatively on a Compulsory or Voluntary Basis

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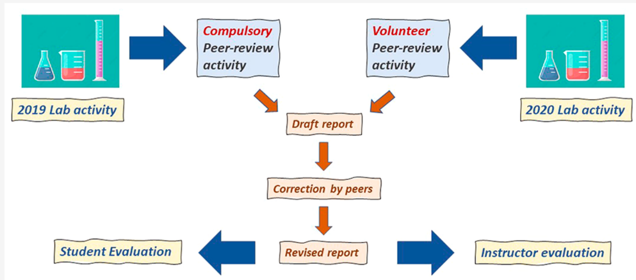
ABSTRACT: A comparative study on the performance and on the perception of two groups of students involved in a peer review activity on the writing of chemical laboratory reports is reported. The first group participated in a compulsory activity, while the second one participated on a voluntary basis. This study was aimed at determining whether the overall activity was more effective when the students voluntarily decided to participate. The results of this study seem to suggest that the use of the peer evaluation method for students in chemistry is partially affected by how the activity is proposed, whether voluntary or mandatory. The student perception, on the other hand, seems to be strongly influenced by whether the activity is offered as an obligation or as a voluntary option. This aspect could therefore foster a deeper and longer beneficial effect on learning for those students participating voluntarily.



KEYWORDS: *Audience/Second-Year Undergraduate, Domain/Organic Chemistry, Domain/Laboratory Instruction, Pedagogy/Collaborative-Cooperative Learning, Topic/Undergraduate Research*

■ INTRODUCTION

Peer evaluation activities have been used in active learning to improve students' skills to write scientific and laboratory reports.[1−8] Numerous examples can be found in the literature, and authors generally report the positive effects of the activity and students' positive attitudes.[9−15]

We recently published in this journal the results of a peer reviewed activity on laboratory reports conducted in an Organic Chemistry class for second-year undergraduate students.[16]

A survey conducted at the end of the activity revealed that the students were overall very satisfied; however, some of them complained about the lack of attention paid by their classmates to their reports and that this had negatively affected the final outcome of their work.

We took on board these criticisms and wondered whether the overall effectiveness of a peer review activity could be influenced by how the activity was presented to the students. The attitude of students in committing to an assignment can be influenced by many factors, among them the organization of the course and how the activity is proposed. We therefore decided to investigate the effects of a voluntary vs mandatory peer review, being aware that this study could not be exhaustive of the complex range of factors influencing students' commitment.

To better understand the reasons for this study, it is necessary to make a point about the peculiarities of the Italian academic system. A striking difference between the Italian and American systems is represented by the different method of exams. In the Italian system, the students are supposed to attend lessons and laboratories during the whole semester and then have two or three months in which lessons are suspended, during which they have different exams scheduled. The exams are usually worth 100% of the grade. In the American system, the final exams are worth only a little percentage of the semester grade, which is calculated by taking into consideration all of the assignments, attendance, midterms, and quizzes the students have done during the semester. Such finals occur right after the end of the class, and students can have more than one final scheduled on the same day—while, in the Italian system, it is more likely that students have the exams spread over the months of suspension. In the Italian system, students can take an exam more than once, if they do not pass it or if they think they deserve a better grade. Moreover, students are not obliged to pass the exam right after the end of the semester, but they can take it after one year or even later. As, especially for scientific faculties, there are subjects that are preparatory to others, the academic system requires students to attend classes and take exams in a certain order. As an example,

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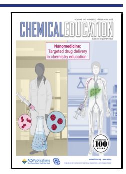

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Biological Science students attend the Inorganic Chemistry classes during the first year and the Organic Chemistry classes during the second. They must pass the Inorganic Chemistry exam before taking the Organic Chemistry one; however, this does not prevent second-year students from attending the Organic Chemistry classes and laboratories even if they have not taken the Inorganic Chemistry exam yet.

Based on our experience, the Organic Chemistry class is quite heterogeneous concerning students' engagement. Among the possible causes, taking into account the above-mentioned characteristics of the academic system, one could be that about half of the students, having already passed the first-year exams (including Inorganic Chemistry), learn Organic Chemistry as they go through the topics explained in class and participate in the activities fully focused on the exam. The remaining part of the students attend the course with the purpose of keeping their pace but knowing that they should pass the first-year exams. We believed that the lack of effort observed in some students was a consequence of this heterogeneity, and we wondered whether the peer review activity would be more accurate if it were offered only to students more focused on the Organic Chemistry class.

Although many studies have reported the positive effects of active learning on motivation and performance,[17,18] there is also some evidence that students' motivation may influence active learning.[19] Students may show resistance to active learning for reasons like: (i) fear of an increase in workload; (ii) anxiety for a lack of self-efficacy in performing as expected; (iii) belief of diverting the focus of attention from the subject to the required activity; (iv) discomfort due to past experiences and expectations about the learning process, where the student expects to receive contents from the teacher.[20] These reasons are linked to two broad attitudes of students toward learning: learning as a passive, teacher-paced process, where their role is limited to note taking and acquiring data, or as a student-centered process, where they are responsible for their learning outcome. The former attitude increases the likelihood of resistance to active learning and can be reinforced or moderated by teachers' approaches to the class, which may show a lack of teaching skills, a disrespect for students, and indolence toward teaching.[21] On the other hand, the latter attitude, where students feel responsible for their learning process, is based on an active approach to study, rich interactions among students and with the teachers, and perception of the meaningfulness of the whole learning path. In line with this, Borrego et al.[22] claim that teachers, to reduce students' resistance to active learning, should use a range of strategies aimed at two main goals: explanation (how they introduce the activity and its purpose) and facilitation (how they promote engagement and provide support along the process).

Focusing on peer review, Liu and Carless[23] argue that the method should clearly distinguish between peer feedback (detailed comments among peers, without formal grades) and peer assessment (students grading the performance of their peers by means of relevant criteria, as proposed in the present research). In addition, they report some issues that elicited forms of students' resistance toward peer feedback activities. These issues are related to

- *Reliability*: students may doubt the seriousness and objectivity of their classmates and could perceive the method as risky and unfair
- *Perceived expertise*: some students could think that their classmates are not professionally equipped with the skills for providing insightful feedback
- *Power relations*: some students may feel unease at giving judgements to their friends, especially when they could be negative; therefore, they could drift toward "friendship marking" (i.e., grades higher than expected) or "collusive marking" (i.e., a lack of differentiation in grades among students)
- *Time*: the procedure is time-consuming and could be perceived as an unbalanced cost−benefit trade-off

Given these issues, we were interested in finding out whether there might be any differences in whether students could choose to do active learning activities or not.

The few available studies concerning the mediating role of prescribed activities/voluntary participation for active learning activities, although not referring specifically to peer review, state that "Prescribed Active Learning Increases Performance" according to Freeman et al.,[24] and "Voluntary participation in an active learning exercise leads to better understanding" according to Carvalho and West,[25] thus suggesting that both mandatory and voluntary work are helpful, potentially in different ways.

With the goal of investigating the effects of voluntary vs mandatory peer review, we decided to compare the overall results of the peer review activity conducted with all students in the Organic Chemistry class in 2019 with a new one conducted in 2020 with only fully engaged students on a voluntary basis. Despite Covid-19 disruption, the activity was structured very similarly with the two cohorts of students, and it is described in detail in the "Study Design" section. The results of this comparison are presented in this article.

Two working hypotheses have been taken into consideration:

H1 - the peer review activity is more effective if carried out with a group of students participating on a voluntary basis

H2 - the peer review activity has a positive effect on the ability of writing a laboratory report

■ METHOD

Study Population

In this research, we conducted a study to compare the overall effectiveness of a peer review activity offered to 37 undergraduates (out of a class of 56) on a voluntary basis in 2020 with the same activity but mandatory for all 64 undergraduates in an Organic Chemistry class, offered in 2019.

Study Design

Prior to the introduction of the peer review activity, students of both cohorts were clearly exposed to active learning with survey methods, group activities and games,[26−28] and solving exercises and problems. Following the EPIC (Expose, Persuade, Identify, and Commit) model proposed by Cavanagh et al.,[29] students were convinced of the benefits of active learning by reporting on the survey conducted with other classes, in which students highlighted the positive aspects of the peer review activity.

The procedure followed by students for the peer review activity was the same for both the 2019 and 2020 classes, but the students of the 2020 cohort were encouraged to engage by the fact that their final exam grade depended also on how they

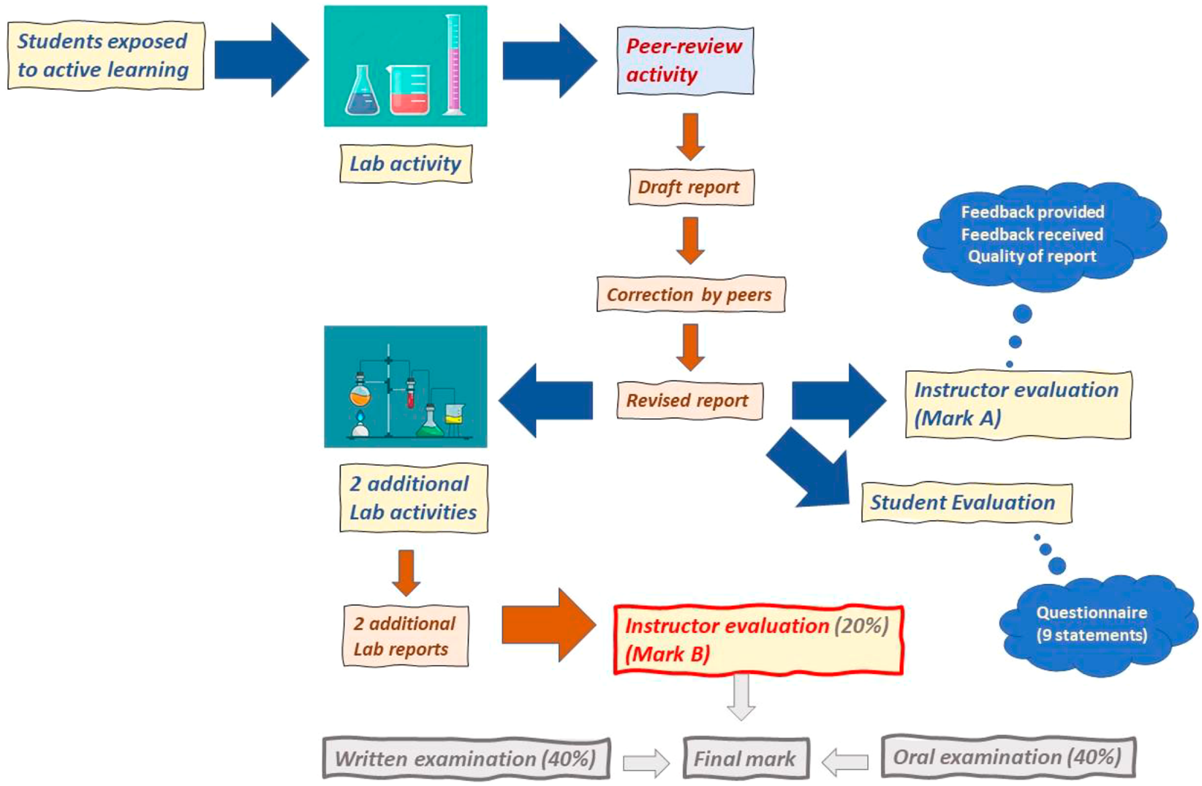

Figure 1. Flowchart of the activity. Students were exposed to active learning prior to starting the peer review activity. After attending a first laboratory activity, students were asked to (i) upload the draft laboratory report, (ii) evaluate the report of their peers and receive their feedback, and (iii) revise their report according to the feedback received. The instructor evaluated the revised reports and provided feedback to the students (*Mark A*). Also, the students evaluated the activity by answering a questionnaire. After the peer review activity was completed, students attended 2 additional laboratory activities and provided laboratory reports (without peer review but, supposedly, with the positive effect of it) that were evaluated by the instructor and marked (*Mark B*). The mark given to these two additional reports composed, together with written and oral examination, the final mark of the exam, that is not included in this discussion.

perform the activity and meet the deadlines. After participating in a laboratory activity, students were asked to upload their lab report to a Moodle platform. Then, an automatic random distribution took place, and each student received the reports from two of their classmates and had 1 week to correct them. Students were given detailed instructions on how to make corrections, according to the Peer Review Guide for students (available in the Supporting Information). Students were not asked to provide a grade but rather a general comment and a point-by-point revision. The procedure was conducted double blind. At the end of that week, each student received two anonymous pieces of feedback. The instructor did not intervene to assess the validity of the corrections at this level. After receiving the anonymous feedback, each student was required to modify his/her draft report and upload the revised version to the platform within 1 week, for correction by the instructor.

Data Collection

Once the submissions were completed, the instructor evaluated not only the overall quality of the reports and their improvement over the initial versions but also the quality of the other participants' feedback and the extent to which it had been critically considered. In analyzing the latter aspects, the instructor also had the opportunity to "rate the evaluators" and check how relevant their feedback was and to what extent they considered all of the aspects required by the guidelines. Evaluation criteria were clearly illustrated to the students before the beginning of the activity.

Analysis was conducted systematically by comparing each final report to its preliminary version, by tracking changes, and by examining whether they were related to the feedback provided by peers. Each student received a final evaluation that considered three different aspects: the quality of the final report, the ability to critically analyze and use the feedback received to improve it, and the quality of the feedback provided to laboratory colleagues. For each of these aspects, each student received feedback and a rating (in the following discussion indicated as *Mark A*) on a scale of 1 (unsatisfactory) to 5 (excellent) based on the Instructor Scoring Grid (Supporting Information, Appendix A).

After receiving the instructor's feedback, students were asked to complete a peer review activity questionnaire; the questionnaire included 9 items asking students to rate on a 7-point scale (from "not at all" to "completely") how accurately each statement applied to them, as well as an open-ended comment. The statements aimed at investigating the students' perception of how well they felt they performed on the assigned tasks and how well they felt their classmates performed on the same tasks.

At the end of the semester, before attending the exam, after having attended two additional laboratory practical activities, all students were asked to submit independently, without any peer review, two additional laboratory reports. These "additional lab reports" were graded by the instructor (in the

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following discussion indicated as *Mark B*) and were part of the final evaluation of the student. The overall quality of these reports was used to evaluate the short-term efficacy of the peer review activity in improving the student ability to write a scientific essay.

In addition, a few months after the end of the semester, all students in the class of 2020 were asked to complete another questionnaire to indicate their reasons for participating or not participating in the activity; 46 students participated in the survey.

A summary diagram of the activity is illustrated in Figure 1.

Statistical Method

The sample enrolled 120 students (70% female); 64 of them attended the course in 2019, and 56 in 2020. 101 students participated in the peer review activity (all 64 students of the year 2019 and 37 volunteer students of the year 2020).

Two linear regression models were performed to investigate **H1** on a subsample of 101 students who participated in the peer review activity in both years: (a) The scores of the laboratory report (*Mark A*) were used as the dependent variable of the model and course year (2019 or 2020) and Inorganic Chemistry mark as predictors. (b) In the second model, the scores of the additional laboratory report (*Mark B*) were used as the dependent variable of the model and course year (2019 or 2020) and Inorganic Chemistry mark as predictors.

A second linear regression model was performed to investigate **H2** using data of 2020 students only, to compare two groups ("peer reviewed" and "non-peer reviewed") who attended the same course under the same conditions. The scores of the additional laboratory report (*Mark B*) were used as the dependent variable of the model and the participation in the peer review activity (yes or no) and Inorganic Chemistry mark as predictors.

A Welch's t test was performed to assess the difference on this variable between the two groups ("peer reviewed" and "non-peer reviewed"). Furthermore, Inorganic Chemistry marks were used as the control variable in both regression models. We used the Inorganic Chemistry mark as a predictor, together with course year (**H1**) or group (**H2**), to distinguish between the influence of past study history of the student from the influence of the method used. In this way, we know how much of the additional report score is due to past knowledge (i.e., how well the student performs in general chemistry course exams) and how much is due to the teaching method used.

■ RESULTS

The peer review activity was evaluated by the instructor (*Mark A*) considering three interconnected aspects: the quality of the revised report ("*revised report*" in Table 1), the ability to critically analyze and use the feedback received to improve it ("*feedback received*" in Table 1), and the quality of the feedback provided to laboratory colleagues ("*feedback provided*" in Table 1). Scores obtained in 2019 for a class of 64 students who participated in a prescribed activity are compared to those obtained in 2020 for 37 students, in a class of 56, who voluntarily participated in the activity. A comparison of average grades for the three aspects listed above is provided in Table 1. Marks ranged in a 1−5 scale according to the grid reported in Appendix A (Supporting Information); more details are reported in Appendix B (Supporting Information).

Table 1. Comparison of the Results (*Mark A*) of a Peer Review Activity Conducted in 2019 in a Prescribed Manner and in 2020 on a Voluntary Basis[a]

Year (students)	Feedback provided	Feedback received	Revised report
2019 (64)	3.25 (s.d. 0.83)	2.91 (s.d. 1.04)	3.31 (s.d. 1.01)
2020 (37)	3.95 (s.d. 0.85)	4.14 (s.d. 0.69)	4.07 (s.d. 0.77)
Δ	+0.70	+1.23	+0.76

[a]The three aspects described in the text have been analyzed separately.

H1: (a) The regression model showed a significant result for all three aspects between the 2019 and 2020 cohorts (i.e., for "revised report": F (2; 98) = 8.504, $p < 0.001$). There is a significant difference between the two groups in terms of the scores of *Mark A* (i.e., for "revised report" $t = 3.527$, $p < 0.001$), but the influence of the Inorganic Chemistry mark was not significant ($t = 1.197$, $p = 0.234$).

As previously described, at the end of the semester, all students were asked to submit independently, without any peer review, two additional laboratory reports. These "additional lab reports" were graded by the instructor. Table 2 shows the mean values of the marks (*Mark B*) of the additional lab reports obtained by students in 2019 and 2020. These marks are based on the grid "Quality of the final report" used for the evaluation of the revised reports in the peer review activity. More details are reported in Appendix B (Supporting Information). Only for the 2020 students, the scores have been separated between those who participated in the peer review activity and those who did not. It is worth mentioning that not all of the students attending the class submitted the additional lab reports right after the end of the semester, as, according to the Italian academic system, there is no obligation to take the examination immediately after the course.

Table 2. Comparison of the Average Grade (*Mark B*) of the Two Additional Lab Reports Submitted by Students of the 2019 and 2020 Class[a]

Year	Participated	Did not participate	Overall
2019	3.45 (56)		
2020	3.95 (33)	2.89 (9)	3.73 (42)

[a]For 2020 only, a distinction is made between students who participated in the peer review activity and students who did not.

H1: The linear regression model was significant (F (2; 98) = 20.12, $p < 0.001$), but it showed no statistical difference in the additional report scores between the students of the two years ($t = 0.417$, $p = 0.677$). Only Inorganic Chemistry marks significantly predicted the score of these reports ($t = 6.028$, $p < 0.001$).

H2: The second regression model was significant again (F (2; 53) = 24.78, $p < 0.001$). Both of the predictors were significant. The participation in the peer review activities has a positive influence on the additional report score ($t = 5.331$, $p < 0.001$), and the Inorganic Chemistry mark is positively correlated to it too ($t = 4.154$, $p < 0.001$).

At the end of the peer review activity, students were asked to evaluate the activity by completing a questionnaire, rating 9 statements on a 7-point scale (1 - fully disagree, 7 - fully agree). The average results are reported in Table 3, while more detailed data are reported in Appendix C (Supporting

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Table 3. Comparison of the Student Evaluation between 2019 and 2020[a]

Statement	2019	2020	Δ	t	df	p
1. The peer review process was clear in all of its parts	5.89	6.22	+0.33	−1.355	43.564	0.182
2. The feedback received by the reviewers was pertinent	5.25	5.38	+0.13	−0.419	46.581	0.677
3. I carefully analyzed my peers' reports	5.68	6.89	+1.21	−5.966	33.099	<0.001*
4. Overall, it was a useful activity	5.46	6.70	+1.24	−5.041	36.222	<0.001*
5. It was easy to follow the different steps of the activity	4.69	5.14	+0.55	−1.551	57.509	0.127
6. The activity allowed me to learn more than traditional study	5.00	6.27	+1.27	−4.664	41.522	<0.001*
7. The feedback received by my peers has allowed me to improve my report	5.71	6.00	+0.29	−0.937	62.870	0.352
8. The corrections I made to my peers' reports also allowed me to improve mine	5.29	6.08	+0.79	−2.771	48.298	0.008*
9. The final version of my report was much better than the first one	5.14	5.84	+0.70	−2.310	49.011	0.025*

[a]P-values marked with * are considered significant, since $\alpha < 0.05$.

Information). *t* tests were performed to evaluate the difference between the two groups.

A few months after the end of the semester, all students of the 2020 class were contacted by email and asked to answer an additional questionnaire, indicating the reasons for having participated/not participated in the peer review activity. 46 students answered, and the results are reported in Table 4.

Table 4. Student Survey on the Reasons for Having/Having Not Participated in the Peer Review Activity

Students who participated in the peer review activity (29)	*n*	%
What motivated you to join the peer review activity? (multiple answers possible)		
Bonus points on final exam grade	21	72.4%
Expectation that participation would give "informal" advantages on the final evaluation	7	24.1%
Personal interest, curiosity	16	55.2%
Collaboration with my peers	21	72.4%
Other	2	6.8%
Students who did not participate in the peer review activity (17)	***n***	**%**
What motivated you not to join the peer review activity? (multiple answers possible)		
Lack of interest in the activity	0	0%
Fear of bad points on final exam grade	2	12.5%
Fear of excessive workload	7	43.8%
Fear of confrontation with my peers	0	0%
Fear of not being able to carry out the activity properly	2	12.5%
First-year mandatory examinations not yet taken	8	50%
Other	2	12.5%

■ DISCUSSION

Before discussing the results, it is worth considering that the voluntary activity carried out in 2020 may have been chosen only by the best students in the course, who inevitably perform better. To remove this bias, it has been decided to take into account the grade obtained by the students participating in this study (belonging both to the 2019 and 2020 class) in the exam "Inorganic Chemistry", which, as mentioned in the Introduction, is preparatory to take the Organic Chemistry exam, and in our opinion reflects with good approximation the student's abilities.

As described in the Introduction, two working hypotheses have been taken into consideration.

Regarding hypothesis **H1** (*the peer review activity is more effective if carried out with a group of students participating on a voluntary basis*), only students who have participated in the peer review activity (in 2019 and 2020) have been taken into consideration, and there was a statistical difference in the laboratory report scores (*Mark A*) between the two groups: voluntary peer reviewed students performed better than mandatory peer reviewed students. As previously reported, one possible risk in this analysis is that only the best students participated in the peer review activity in 2020. For this reason, the grade obtained by each student in the Inorganic Chemistry exam has been taken into consideration. This difference has been accounted for in all of the analyses, by including the Inorganic Chemistry grade in the regression model used to assess whether there are significant differences between the two groups.

On the other hand, analysis of the evaluation of the additional laboratory reports (*Mark B*) showed no statistical difference between the students of the two years, while Inorganic Chemistry marks significantly predicted the score of the reports. Thus, although peer review activity seems to work better when conducted on a voluntary basis, this does not seem to significantly influence the short-term effect.

Regarding the student perception, there is a significant difference between the student evaluation in the two years (Table 3). In 2020, higher scores have been obtained for all statements, with higher differences ($\Delta > 1$) for statement 3 (I carefully analyzed my peers' reports), regarding student self-commitment, and statements 4 and 6 (Overall, it was a useful activity; The activity allowed me to learn more than traditional study), related to overall satisfaction. Interestingly, statement 2 (The feedback received by the reviewers was pertinent) did not show a significant improvement. Concerning the decision to take part in the activity in the 2020 cohort, the statements reported in Table 4 reveal that expectation of formal and informal advantages played a role as important as less "instrumental" motivations such as personal interest, curiosity, and collaboration with peers.

Regarding hypothesis **H2** (*the peer review activity has a positive effect on the ability of writing a laboratory report*), only data from the year 2020 were considered. Out of the 56 students who attended the Organic Chemistry course, 42 submitted the final laboratory reports for evaluation, prior to giving the final exam. 33 of them participated in the peer review activity, and 9 did not. In order to check that the students who participated in the peer review activity were not also the best prepared, the grade in the Inorganic Chemistry exam was again used. The results showed that participation in the peer review activities has a positive influence on the exam report score and that also the Inorganic Chemistry mark was positively correlated to it.

It is interesting to note that, in regard to the reasons why students did not take part in the peer review activity (Table 4),

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the most popular ones were fear of high workload and first-year exams still due. These answers are in line with some of the reasons for resistance discussed above.[23] Lack of interest for the activity and fear of confrontation with peers were not mentioned.

■ CONCLUSION

In conclusion, we have reported a comparative study on the performance and on the perception of two groups of students involved in a peer review activity on the writing of chemical laboratory reports. The first group was involved in a prescribed activity, while the second one participated on a voluntary basis. The results of this study seem to indicate that the peer review activity leads to better results when the students involved participate voluntarily, as evidenced by the improvement in the grade given to the activity (*Mark A*) between 2019 and 2020. However, the positive effect of peer review in the ability to write a scientific report (short-term effect) occurs regardless of whether the activity is compulsory or voluntary, and is evident in the comparison of *Mark B* between those who performed the peer review activity and those who did not in 2020. The student perception, on the other hand, is strongly influenced by whether the activity is offered as an obligation or as a voluntary option. We are aware that taking into account only the grades is a limited form of operationalization of the effectiveness of the peer review. Its value does not rely just on the increase of students' performance during the exam but should favor a deeper and more durable form of learning that goes beyond the exam. For this reason, we believe that students' perception of the value of the activity could not only promote learning for the exam but could also enable them to activate metacognitive processes and deeper understanding of the subject. Therefore, notwithstanding our results demonstrating a beneficial effect of both peer review modalities in the short-term, the voluntary approach could favor students' appreciation and therefore produce longer and deeper positive outcomes. As stated by Ryan and Deci,[30] "Students can perform extrinsically motivated actions with resentment, resistance, and disinterest or, alternatively, with an attitude of willingness that reflects an inner acceptance of the value or utility of a task. [...] Frankly speaking, because many of the tasks that educators want their students to perform are not inherently interesting or enjoyable, knowing how to promote more active and volitional (versus passive and controlling) forms of extrinsic motivation becomes an essential strategy for successful teaching." Within this perspective, additional studies on the motivation of students will be performed in due course.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.2c00229.

Appendix A (Instructions for reviewers and instructor scoring grid), B (Instructor evaluation (*Mark A* and *B*) and Inorganic Chemistry Mark for 2019 and 2020 cohorts), and C (Student evaluation for 2019 and 2020 cohorts) (PDF)

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Author Contributions

T.F.P.: Statistical analysis, review and editing. A.B.: Conceptualization, supervision, methodology, investigation, writing - original draft. F.B.: Supervision, writing, review and editing.

Notes

The authors declare no competing financial interest.

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