Toward improving collaborative behaviour during competitive programming assignments

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***Abstract*—Competitive gamification has been successfully used to improve the learning experience in computer science courses. Assignments based on high-performance and parallel programming contests have been shown to be highly effective to promote the interest and involvement of students. Nevertheless, during programming-contest assignments the competitive approach sometimes diminishes the usual collaboration between students to solve basic questions and common difficulties; for example, those related to the usage of the programming languages or tools. In this paper, we present an approach to integrate collaborative gamification techniques with the competitive elements of programming contests, in order to balance both aspects and to enhance the overall learning experience. The results show that this approach effectively promotes participation and collaborative behavior during a programming contest. They also reveal potential improvements that can be considered for this approach.**

***Index Terms*—Gamification, collaboration, competition, programming, contests**

I. Introduction

Gamification is a term coined for the use of game design elements in non-game contexts [3]. It has been shown that the use of gamification in education affect the learning outcomes of students [1], their behavior [7], and their motivation or engagement [9]. The engagement in an active learning context promotes the desire and willingness of the students to be successful [5]. Teachers can take advantage of these potential benefits by including game design elements and common features of video-games into the learning context.

Programming-contest assignments are a classic gamification activity to promote the involvement of students in programming skills learning [10]. In the field of High Performance Computing (HPC), students should develop programming skills and abilities related to code optimization and parallelization techniques. These techniques have complex interactions among them, and with the machine architecture details. The results of their application are difficult to predict for new students. Nevertheless, the result can be easily measured experimentally in terms of performance. This introduces an objective measure of success that can be automatically obtained by an on-line judge to create a ranking. Thus, programming-contest activities are adequate for HPC learning, and we have successfully used them in the context of a Parallel Computing course [6].

Nevertheless, we have observed that the competitive behaviour during the programming contests sometimes interferes with the usual collaboration between students to solve basic questions and common difficulties; for example, those related to the usage of the programming languages or tools. However, the collaborative and competitive processes are interrelated [2]. More recent studies also show that the combination of competition with collaboration is particularly effective in the gamification context for promoting behavioral learning outcomes [8].

This paper presents an approach to introduce collaborative gamification using rewards (such as prizes or badges), and evaluation of the students' participation, in a collaborative on-line platform. The tool chosen is a text-based forums platform where students and teachers interact to solve questions related to the programming contests and assignments. The platform is enhanced to support both technical and social acknowledgement from other students to threads and comments. The evaluation is based on both the volume of participation in the forum, and the acknowledgement or recognition from other students to their contributions. Prizes and badges are obtained by accomplishing specific tasks related to the students communication in the forum. We present a summary of the results collected during a test experience using this approach in a real Parallel Computing course with a strong competitive gamification component in terms of programming-contest assignments. We discuss quantitative measures about the use of the forum tool and the results of a survey to gather information about the students' perception of the learning experience. These results indicate that this approach can effectively improve participation and collaborative behavior during the programming contests. They also reveal further

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improvements that can be considered for this approach.

The rest of the paper is organized as follows: Section 2 presents the proposed approach. Section 3 describes a test experience conducted using this approach. Section 4 discusses results collected about the students' perception of the experience. Section 5 presents the conclusion and some future work.

II. A COLLABORATIVE GAMIFICATION APPROACH

In this section we describe a gamification activity designed to improve the students' collaboration during the whole course, and specifically during the competitive programming assignments.

Our approach introduces collaborative gamification using prizes, badges, and a quantitative evaluation of the participation of the students in a collaborative on-line platform. The tool chosen to implement the activity is a text-based forums platform, enhanced to support both technical and social acknowledgement from other students to the posts (threads and comments). Teachers also participate in the forum, guiding the discussions when it is needed, and helping the students to discover proper solutions.

A. Collaborative Forum implementation

In our case, the forum is implemented using the Moodle virtual-teaching platform available at the University of Valladolid. All the students enrolled in the course are automatically registered as members of the forum, and they receive emails when other members (teachers or students) post in the forum. The social acknowledgement is implemented using the peer-to-peer grading mechanism provided by Moodle in the forum activity module. This mechanism allows forum members to award a *grade* to posts of another member. Grades are intended to be a numeric value. For our purpose we create a new Moodle's grade scale with only two grades.

- **Like/Educational (value 1):** To reward interesting contributions in general.
- **Useful/I'm using it (value 2):** To reward contributions that are immediately useful for the development of the programming assignments of the user rewarding it. The students are encouraged to explain in the assignment essays how they used the particular contributions they rewarded with this grade.

A member can award at most one grade to each specific post of another student, and a post can receive several grades from different members. We use the term *acknowledgement token* for each grade awarded to a post from a different user. The forum module register the amount of acknowledgement tokens of each type awarded to each post. Only the teachers can query who is awarding each particular one, but the tool shows the number of awarded tokens and their total value to all the members when they navigate the forum. This also provides to the students an easy method to identify the posts considered more useful by their peers. See an example of the forum interface in Figure 1.

We customize the appearance of the grade labels in the forum tool. We introduce a UNICODE character on the label of the different values, that is visualized by standard navigators as a representative icon. The first type includes a *thumb-up* icon. The second type includes a *wrench* icon. Thus, students can easily identify the type of grade by its icon when awarding them or when querying the rewards they have received.

B. Gamification by rewards

The forum tool is presented to the students as a channel to ask/solve any questions about the course, and specifically about technical questions of programming techniques or languages. To *break the ice* the teachers also initiate some threads with particular questions that are useful for all students and relevant for specific assignments. Special rewards can be associated to correct answers or further questions in these threads.

The most used and deployed game design elements in educational contexts are rewards (e.g. points and badges), and competition elements (e.g. leaderboards) [4]. To encourage participation and to avoid the excess of secrecy during the competitive assignments, we design reward tools for contributing information that is useful for other members of the forum. We design them in a similar way as the ones used in the competitive gamification. We want to promote the perception that a loss in the ranking associated to the competitive assignments, due to disclosure of useful information for competitors, can be compensated by a higher grade in the Collaborative Forum. The proposed rewards include:

- Social acknowledgement: Implemented with the acknowledgement tokens received from other students.
- Badges: Badges are awarded to students for special achievements. They have no direct impact in the grade of the student, and they simply appear as trophies in their profiles. We introduced them previously for competitive gamification. We extent the current list of course badges with new ones for special collaborative achievements in the forum. Some of the badges are secret until students trigger and reveal them. Some examples include:
  - **Wizard of forOz:** Achieve at least 10 acknowledgement tokens from other students.
  - **Super-useful:** Achieve at least 5 *Useful/I'm using it* acknowledgement tokens from other students.
  - **First technical problem (secret):** Start the first thread with a question about a technical issue with the tools to launch programs, the on-line judge, etc..
  - **First content problem (secret):** Start the first thread with a question about the content of the programming assignments, or about issues with the programming languages.
  - **Bug killer:** Post a potential bug in the original sequential programs that can affect the results when parallelized.
  - **Master of the formula/Apprentice of the master of the formula:** They are examples of specific badges for a thread started by the teachers. They are awarded to the students that: (a) post in the forum at least three really different valid formula to compute a global index

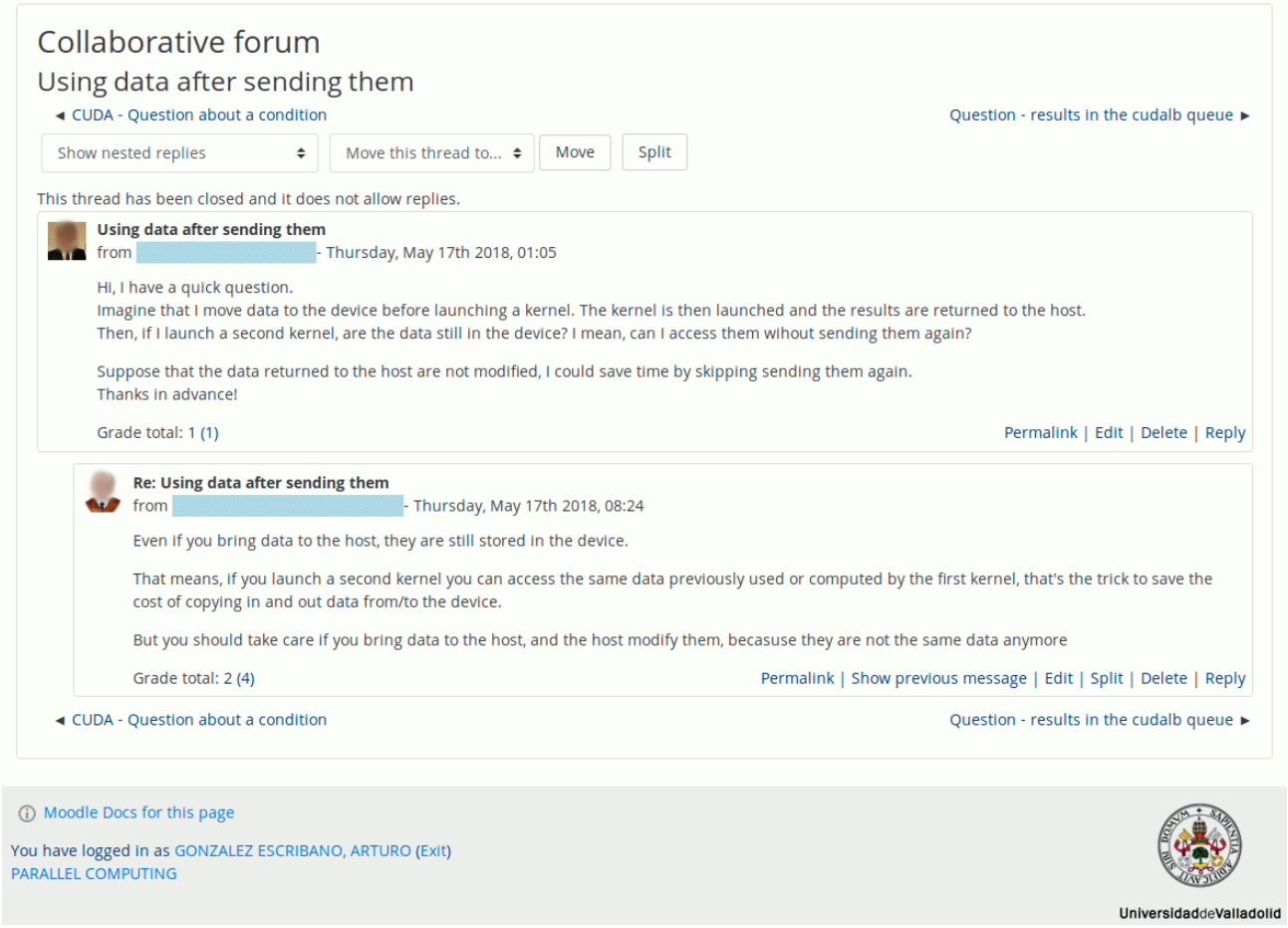

Fig. 1. Example of the Collaborative Forum interface implemented using the forum activity of the Moodle platform. The example shows one short thread with a single reply. The thread is closed after the end of the course activity. Acknowledgement tokens have been awarded to both posts. The grade indicates first the number of tokens received, and their total value enclosed in brackets. The texts have been translated to English and student's data have been anonymized.

for CUDA threads in two-dimensional grids; (b) post at least one.

  - **Beep beep:** Post a reply to a question in less than two hours since the question is posted, and receive at least three acknowledgement tokens in the reply.

- Grade: Finally, the volume of participation of each student is measured in terms of: (a) the number of posts in the forum; (b) the total number of acknowledgement tokens awarded to other students; (c) the number of posts with at least one acknowledgement token; (d) the total number of acknowledgement tokens received. These numbers are normalized taking into account the total volume of participation on each category. A formula with different weights is used to compute a value that is added to the final grade of the students. This value can be up to 10% of the maximum grade that can be obtained in the course. If the sum is higher than 100%, the final result is adjusted to 100%.

III. Pilot Experience

This section discusses a pilot experience using the proposed approach, and its implementation, in a *Parallel Computing* course of the *Computer Engineering Grade* at Universidad de Valladolid (Spain). The Computer Engineering career is organized in a Grade (4-years), and a Master (1-2 years). The Parallel Computing course is taught as a major elective course during the 3rd year of the Grade. Approximately 50% of the students attending courses of the third year choose it.

Our Parallel Computing course has implemented competitive gamification for several years with success. The collaborative gamification activity described in the previous section is introduced without changing any other procedures or elements of the course. The full set of anonymized data collected during the experience is available under request to the authors.

A. Participation of students

This section summarizes the observed participation of the students in the course activities, in the Collaborative Forum, and other means of collaboration detected during the course.

The experience was conducted with 50 students enrolled in the course. One student did not participate in the activities or exams. Ten more students did not pass the minimum grade after the regular course activities. The rest of the students

obtained grades with an almost linear distribution between the minimum (50%) and the maximum values (100%).

The amount of participation in the *Collaborative Forum* is not as much as expected for the number of students enrolled in the course. There are 16 threads, 11 of them started by the students and 5 started by the teachers. In total, there are 92 posts of students. Only 30 students published at least one post. Considering only these students, the mean number of posts per student is 3.06, and the maximum is 10 posts.

There are 19 students with at least one acknowledgement token in their posts. There are a total amount of 108 acknowledgement tokens, with 74 of the *Like/Educational* type (10 of them awarded to the teachers), and 34 of the *Useful/I'm using it* type (7 of them awarded to the teachers). Considering only the students that received at least one token, the mean number of acknowledgement tokens per student is 4.79, and the maximum is 12.

The relation between posts and acknowledgement tokens awarded or received is quite irregular, with students posting no more than 4 posts but awarding up to 12 tokens to other forum members, and one student posting 10 posts and awarding only 4 acknowledgement tokens. There are different profiles depending on the previous experience and knowledge of the students. Some of them help more, some of them appreciate the help more. Some specific posts accumulate a lot of positive feedback in terms of acknowledgement tokens, as they contain critical help. Nevertheless, the students with more acknowledgement tokens accumulated have several posts with positive feedback, indicating a good level of implication and assistance, that really deserves the obtained reward. These results indicate that the reward tools associated with the Collaborative Forum work properly, promoting the expected behavior.

B. The Telegram group of the students

During the course the teachers realized, thanks to indirect information, that there was active communication among students using an alternative channel. The students of the Computer Engineering Grade at the University of Valladolid created several years ago a communication group using the mobile app named *Telegram*, similar in functionality to *WhatsApp*. This group is used for general and specific questions about any subject or course of the Grade. Students of any year and old students, some of them even already graduated, do participate in the group. The teachers of the Grade are not involved or invited to participate in it.

The teachers of the Parallel Computing course were informed that some questions and issues about the competitive assignments and activities of this course appeared in discussions conducted using the Telegram group. Thus, part of the collaborative activity that we expected to be reflected in the Collaborative Forum has been derived to the Telegram group. This partially explains the quantitative measures of participation in the forum. This situation happened despite the appeal of badges and the potential benefits in terms of grade improvements associated with the forum usage. The main reasons for this derivation, and potential solutions, are discussed in the following section.

IV. Students perception

Feedback is gathered from students through a survey. This survey tries to measure improvement of motivation, subjective learning, and the impact of the specific collaborative activity. The survey was conducted more than 15 days after the end of the activities of the regular course, in order to avoid the direct influence of the emotions produced by them.

The survey includes 8 questions using the Likert scale with 5 values (from 1 to 5), with neutral perception centered in the value 3. It also includes one question with multiple answers about the reasons to use an alternative tool instead of the Collaborative Forum, and a free text field for general observations and suggestions. The questions in the survey are:

Q1: Are you satisfied with the general experience of the course, the kind of activities, grading methods, etc.?

Q2: Do you think that the relative weight of contests and assignments in the final grade is right with respect to the theoretical exams?

Q3: To which degree do you think the competitive parts of the course (contests, badges) are adequate, make the course more interesting, and encourage a more active participation?

Q4: To which degree do you think a tool that allows the communication among students, to solve questions or to help in the development of the programming assignments, is appropriate for this course (like the *Collaborative forum*, a *Telegram group*, etc.)?

Q5: To which degree do you think the *Collaborative Forum* or the students' *Telegram group* have really improved or promoted the collaboration among students?

Q6: To which degree do you think the *Telegram group* is a better option for students' communication than the *Collaborative Forum* created in the virtual teaching platform of the University?

Q7: Do you think that the *Collaborative Forum* have been used less or more than the *Telegram group*?.

Q8: Tick the reasons that you think have motivated the students to use sometimes the *Telegram group* instead of the *Collaborative Forum*:

a) It is faster and more comfortable to query or to receive feedback.
b) It is more intimidating to post in the *Collaborative Forum*.
c) There is more people in the *Telegram group*, including older students of this course from previous years.
d) The teachers of the course do not have access to the *Telegram group*.
e) Other reasons (please, explain them in Q10).

Q9: Have you used, participated, or queried frequently the *Collaborative Forum* during the course?

Q10: Free text: Add any observations you have about the course, the collaborative activities, suggestions to improve the learning experience, etc.

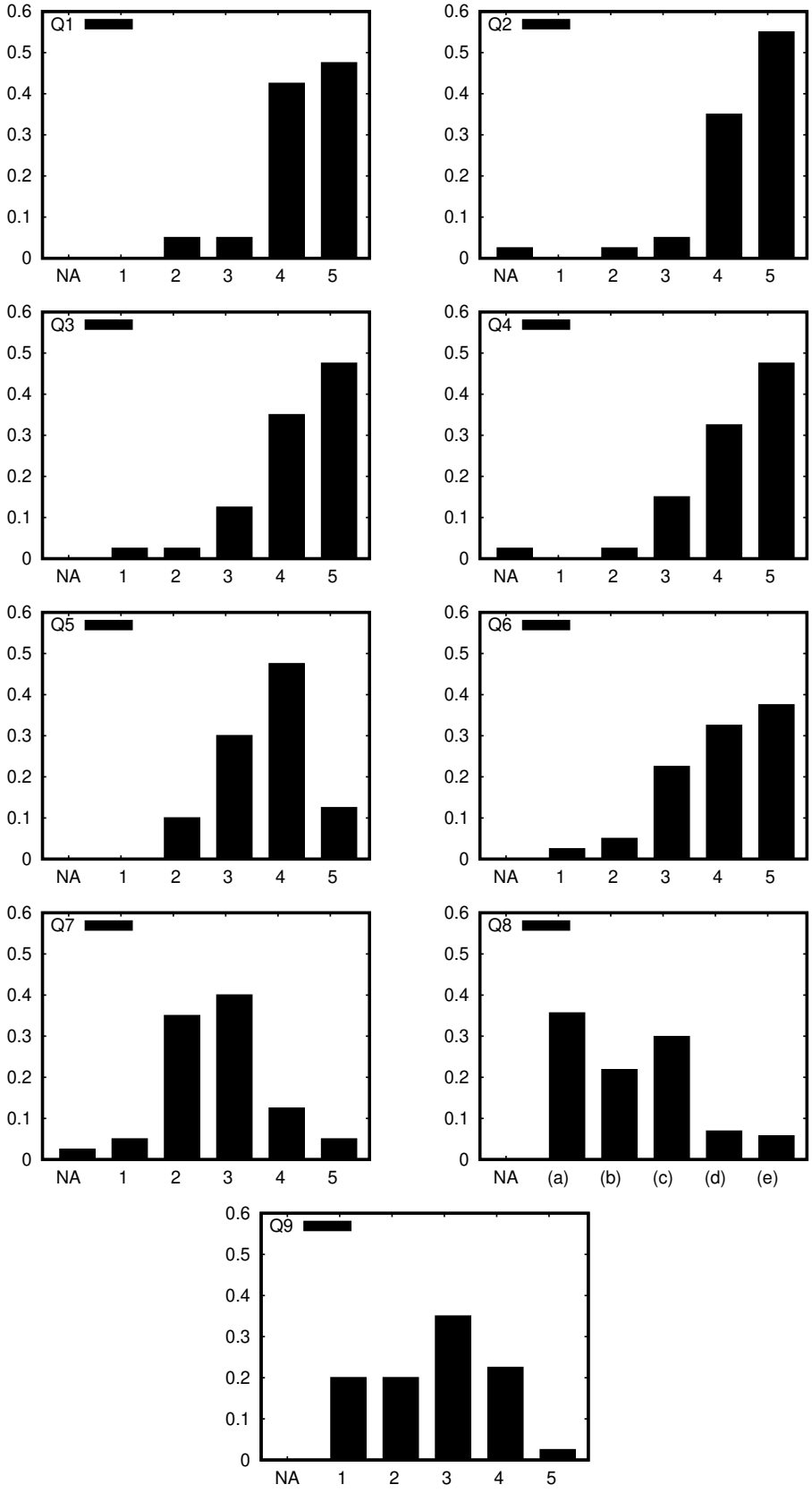

Fig. 2. Histograms showing the relative frequency of answers to each question of the student's survey.

The survey was filled up by 80% of the students. The histograms in Figure 2 show the relative frequency of each answer. Observations about these results follow.

a) Answers to Q1 and Q2: The results of Q1 and Q2 show that the overall perception of the students about the learning experience, and the grading weights for the different type of activities, is quite good, with more than 95% of the answers in values 4 and 5.

b) Answers to Q3: In question Q3 we observe that most students think that the competitive activities improve the participation in the course. However, there are some students that are not sure, or disagree. These students perceive that the collaboration is degraded during the competitive activities. This is confirmed in some cases by the comments in the the free text of Q10. Some more students also comment about this problem in Q10, but still grade this question with the value 4. They like the competitive experience but they also think that the collaboration could be improved.

c) Answers to Q4 and Q5: In the results of Q4 we observe that most students think that a tool for students' communication is really important. But some of them are not sure that the tools used during the course can yet solve the perceived problem. The exact implementation used during the course is more clearly questioned in Q5. Although the overall result is perceived as positive, most students also think it can be improved.

d) Answers to Q6, Q7 and Q9: In Q6 the students express an overall preference for the format of the *Telegram group* for students' collaboration over the *Collaborative Forum* implemented by the teachers. Q7 measures the perception of the students about how much the *Collaborative Forum* has been used in comparison with the *Telegram group* during the course. It shows that, in general, the students perceive that the Telegram group has been used even more than the Collaborative Forum. Q9 shows that many students do not think they have participated a lot in the *Collaborative forum*.

e) Answers to Q8: In order to design a better solution for next editions of the course, Q8 is introduced to get hints about the reasons of the students to use the *Telegram group* instead of the *Collaborative Forum* introduced by the teachers. It is a multiple answer question. The most frequent answer is that the Telegram mobile app is faster and more comfortable to interact with. Several specific details reinforcing this idea are further detailed in the free text Q10 by several students. The second most frequent answer is that in the Telegram group they can communicate with other people, including students from previous editions of the course, who are already familiar with the specific problems of HPC programming. The third most frequent answer indicates that the forum is also intimidating. Some free text answers in Q10 further specify that the format of the forum is less colloquial, promoting a fear of looking ridiculous due to posting too simple questions or wrong answers. Very few students indicate that the access of the teachers to the discussions could be a major problem. Thus, the main focus is on the agility and accessibility of the communication tool, and the help of more experienced students that have already pass the course.

f) Other details in answers to Q10: Another interesting point for improvement has appeared in some comments in Q10. The two categories designed for acknowledgement tokens in the Collaborative Forum are sometimes confusing. A single *Like* button could simplify the immediate response. Nevertheless, a more free scheme could also be implemented to allow the students to use different icons or grade categories, with the same impact, but different emotional connotations.

To summarize, the results indicate that the competitive activities improve the learning experience, but some kind of reinforcement for collaboration is adequate. The students make a strong point about the idea that more agile tools for students' discussion would be more appropriate than the current implementation of the *Collaborative Forum*. Implementing a solution that allows older students of the course to participate in the discussion, in an environment with teachers access and control, requires further study and discussion.

V. Conclusion

This paper presents an approach to encourage collaborative behaviour in courses with a strong component of competitive activities, as programming-contest assignments. The approach is based on designing collaborative gamification activities that complement the competitive components. We describe a specific implementation of the approach used in a real course, and we present a discussion of the results. The results indicate that this implementation reinforce and complement the competitive activities, improving the learning experience. Nevertheless, some lacks are detected and improvements and solutions are discussed, including using of a more agile communication tool than the implementation of the Collaborative Forum used in this pilot experience.

Future work includes testing the proposal with a higher number of students and more groups to obtain stronger conclusions, and generalizing them by testing the approach in other courses and universities. In the technical part, future work includes using a more agile tool based on a mobile app, designing and testing more powerful rewards, calibrating the teachers participation in the activity, or introducing new gamification activities to further reinforce the collaboration.

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