ABSTRACT

Like many institutions, our University switched to virtual classes during 2020 and 2021 because of COVID-19 pandemic. Adapting our Software Project capstone course to this format was challenging, since students work intensively in teams to develop software for an external client. In-person academic activities resumed in 2022, so we designed a hybrid version of the course, aiming to improve teamwork quality by bringing together the best of both worlds: virtual software development with in-person presentations and client meetings. In this paper, we analyze the effectiveness of this redesign, by comparing the results of conducting a survey over two semesters: Virtual (2021-2) and Hybrid (2022-1). We found that students in the virtual semester evaluated teamwork in a positive manner, mainly because of the sense of belonging that it created, resulting in more cohesive teams. Conversely, teamwork was more challenging in the hybrid course, where students’ perceived that some individuals were less committed to the project, affecting the overall workload balance. Although the hybrid format addressed some of the drawbacks of the virtual format, it did not lead to a clear improvement in teamwork quality as a whole, contrary to our expectations. We hypothesize that this is because students now had other in-person socialization opportunities and no longer relied on team projects to help alleviate the sense of isolation they endured during the worst of the COVID-19 pandemic.

1 INTRODUCTION

Teaching students’ about teamwork contributes to their personal development and their learning experience in different areas. Moreover, it also prepares them for their professional future, allowing them to recognize their strengths and work on their weaknesses, developing professional accountability, as well as tolerance and peer respect [5]. Teamwork has particularly been recognized as a relevant skill in software development. Traditionally it was considered valuable for large systems but currently it is also an essential part of agile software development [7]. Teaching agility and more specifically developing teamwork skills has its challenges: students take different courses simultaneously, projects must be developed within the course duration and students must choose the agile practices that best contribute to the success of the project [15].

Software Project is the last mandatory course of a combined Computer Science and Software Engineering undergraduate program at the University of XX. Students work 16 hours per week, in teams of 5 to 7 people, developing a real application for an organization that is external to our department, applying a series of agile practices. An instructor is in charge of the course, organizing and grading the learning experience, and each team has a tutor, who mainly provides advice about technical issues.

Until 2019, all activities in the course were in-person. Due to COVID-19, during 2020 and 2021 the course was completely online, i.e., all meetings, development activities and presentations. In order to understand how students were adapting to virtual work, we surveyed students’ perceptions about teamwork [1] at the end of the final 2021 semester. In-person activities resumed at the beginning of 2022, which meant that we could return to the original course format. However, taking into account the opinions that students had previously expressed in the survey, we decided to transition to a new hybrid format: virtual software development activities with some in-person activities, like presentations and meetings. The need for a hybrid format is consistent with the current industry trends, where some people will work from home with some regular in-person interactions [18], so students should be prepared for this hybrid work scenario. So, in order to analyze the impact of this new hybrid format on teamwork quality, we repeated the survey from [1] during the first hybrid semester. In this study, we report our main findings when we compared students’ perception about teamwork in both formats of the course.

We found that, contrary to what we expected, student perception about teamwork quality was better during the Virtual version of
the course. The only aspect that improved in the Hybrid format was related to feelings of isolation. Some of these results are in line with those reported by Haslam et al. [11], where they found that students that have worked in team projects had a more positive experience with online learning, challenging the idea that problem-based learning mainly relies on in-person interaction. We hypothesize that during the Hybrid semester, students needed to attend other in-person courses that made it complex for them to devote the 16 hours per week demanded by this course.

2 RELATED WORK

2.1 Teamwork quality

Teamwork is a highly valuable skill for software engineers provided that it directly affects project results and thus it has the potential to be determinant in professional success [14]. That is why most software engineering programs include courses that focus on teaching and training teamwork [2] [3]. Success, in the context of teamwork, involves several points of view such as effectively completing the assigned tasks or more social dimensions, where members actively invest on building effective working relationships [8].

There are technical and psychological characteristics that make a person better suited for teamwork. Technical/innovation competencies, management skills or team leader behavior are highly appreciated [20], but also emotional stability, extraversion, openness, agreeableness, and conscientiousness [9]. Team confirmation may also affect teamwork [10]: team size, time availability, experience, motivation and gender, among others.

According to Hoegl [12] and Linsdjar [13], working in teams can be evaluated from different points of view. Their work considers three categories: teamwork quality, team performance and personal development. Teamwork quality refers to social interaction and synergy between students and considers six variables: communication, coordination, balance of member contribution, mutual support, effort and cohesion. Team performance indicates the ability of the team to reach the project goal in time and with high quality; it considers efficiency and efficacy. Personal development is specially relevant provided that we are dealing with a course; it considers knowledge and abilities acquired as well as the satisfaction with the work done. In this work we use these dimensions for designing the survey for gathering students’ perceptions about teamwork quality in order to compare the the virtual and the hybrid formats of the course [1] (see Table 1).

Nevertheless, teamwork is successful only if its results are good in any sense, e.g., software quality, cost, scope, or time [7]. Although the quality of the resulting software is independent of the team organization, if results are poor, no other dimension could be considered as satisfactory.

Bayer et al. [4] compared different dimensions of teamwork quality in a Political Science capstone course. They consider several semesters where the course was given in-person, virtual and hybrid, as is our goal in this paper. They found that there are some dimensions of teamwork that students perceive as more valuable such a team belonging, that resulted better in a virtual format, contrary to what they expected but consistent with our own findings.

<table>
<thead>
<tr>
<th>Table 1: Teamwork dimensions (from [1][12][13])</th>
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</thead>
<tbody>
<tr>
<td>Communication</td>
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<tr>
<td>Coordination</td>
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<tr>
<td>Balance of member contribution</td>
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<tr>
<td>Mutual support</td>
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<tr>
<td>Effort</td>
</tr>
<tr>
<td>Cohesion</td>
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<tr>
<td>Efficiency and Efficacy</td>
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<tr>
<td>Satisfaction and Learning</td>
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<tr>
<td>Virtual/Hybrid mode</td>
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</tbody>
</table>

2.2 Transition between different work models

There have been several works reporting on the challenges that software development faced shifting from in-person to virtual scenario due to COVID-19 pandemic both in teaching software engineering courses and in industry.

The change to a virtual format was sudden and with almost no previous planning and resulted in courses with little structure. Even though students were flexible and forgiving with the difficulties, they still had trouble with motivation and recognizing the real knowled they were acquiring [16]. A large number of instructors around the world reported that grading had to be adjusted, focusing more on projects than in-class exams for all software engineering courses [17].

In industry, transitioning from in-person software development to a virtual or hybrid scenario [6] lead in some cases to a decline in work satisfaction and even frustration from the challenges. That is why it has been important to take advantage of the few in-person instances, to carry out collaborative work and social interactions.
Capstone courses in essence intend to resemble industrial practice, so these courses must consider current trends and lessons learned from the virtual scenario adopting the elements that resulted successful [18]. While there are several works presenting research on the transition between in-person and virtual forms of capstone courses, there are very few addressing the transition from virtual to hybrid formats.

For example, Stahr and Davis [19] highlight the relevance of still having a final event in capstone courses where all stakeholders take part, i.e., students, instructional team and clients, and they describe the complex technological setting that was required to make it possible in a virtual scenario.

3 COURSE DESCRIPTION

Software Project is an advanced software engineering course, which undergraduate students take during their last semester at our CS Department. This course is offered every semester, and has had the same instructor for the past decade. This instructor designed the Virtual and Hybrid formats of the course, based on evidence from the literature and their experience with the course. Projects range from video game development, to fleet-tracking automation, to mobile application development, among others.

During the semester, students work in self-organized teams of 5 to 7 students, developing a software solution for an external client (e.g., not from within the CS department). Each student must work a total of 16 hours per week and each team has a weekly meeting with the instructor for guidance and active reflection. The 15-week semester is divided into a two week introduction and three iterations of 4, 4 and 5 weeks where students work on their projects. At the end of each iteration, teams demo their project advances and hold a retrospective. Here they discuss good and bad experiences, including, but not limited to, the use of technology, project planning, and team and client relationships. Projects are graded at the end of each iteration: the instructor evaluates the quality of the software and team project management skills, while students assess their peers’ teamwork skills.

The course has been taught for almost 20 years with evolving formats, starting with a more traditional strategy that followed the classical waterfall model, to a more agile format. The current format that requires certain agile practices, such as iterative development, continuous integration, time-boxing and shared code ownership. Other agile practices, such as daily meetings, and peer-programming.

Until the end of 2019, this course was completely in-person, with students working in-person at the client’s organization. However, with the COVID-19 pandemic, it had to be switched to a completely virtual format one week into the first semester of 2020, which meant that there was almost no time to analyze alternatives. Software development activities, meetings with the client and the instructional team, as well as presentations had to be moved online.

At the beginning of 2022, all courses at our university started to gradually incorporate in-person activities. In a survey [1] applied during the virtual semesters, students had highly valued working virtually instead of in-person at the client’s organization, but they also craved human interaction. To address this weakness, the course was redesigned to be hybrid: software development activities and weekly meetings with the instructor remained virtual, while presentations were now in-person. Teams were also asked to have at least one in-person meeting with their client during each iteration.

4 TEAMWORK QUALITY COMPARISON

The changing scenario from an in-person to a virtual format of the course was in response to an external situation. Transitioning from virtual to hybrid intended to preserve some elements that have been valued by students while introducing others that were thought to address the identified weaknesses.

As discussed in Section 2, teamwork quality can be evaluated from different points of view. Additionally, both the Virtual and Hybrid formats have effects on the development of interpersonal relationships, which can affect teamwork. As such, we have identified the following research question (RQ):

Are there significant differences in students’ perception of teamwork quality between the Virtual and Hybrid formats of the course?

We conducted a survey in order to answer this question, comparing teamwork quality between the last Virtual semester (2021-2) and the first Hybrid semester (2022-1). Both semesters have the same instructor, similar client projects, and a similar level of student enrollment. The main difference is the course format (Virtual versus Hybrid). In order to collect students’ perceptions of teamwork quality, we applied a questionnaire that considers the teamwork dimensions listed in Table 1. This questionnaire has 40 questions, which are listed in Table 3 [1]. Each question is evaluated on a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The goal of this study is to understand the effects that the course format has on the different dimensions of teamwork quality.

5 SURVEY: RESULTS AND ANALYSIS

The questionnaire was applied at the end of two semesters – Virtual (2021-2) and Hybrid (2022-1) – right before the final grades were made available to the students, in order to minimize bias. Answering the questionnaire was optional. Table 2 indicates the number of students enrolled in the course during each semester, as well as the response rate for the questionnaire.

Table 2: Enrollment and response rate, per semester

<table>
<thead>
<tr>
<th>Semester</th>
<th># Students</th>
<th># Responses</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual 2021-2</td>
<td>58</td>
<td>31</td>
<td>53%</td>
</tr>
<tr>
<td>Hybrid 2022-1</td>
<td>44</td>
<td>27</td>
<td>61%</td>
</tr>
</tbody>
</table>

5.1 Results

Table 3 shows a summary of the responses we received, grouped by teamwork dimensions and semester. Columns SD, D, N, A, and SA represent the number of Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree responses. The positive response rate for each question was calculated by adding the Agree and Strongly Agree responses, and can be found in the %P column for each semester (V and H for the Virtual and Hybrid semesters, respectively). We have highlighted in green the 10 values of %P that were higher for the Hybrid semester, compared to the Virtual semester.
Most of the higher positive response rates for the Hybrid semester can be found in the Virtual/Hybrid mode dimension (6 out of 9 questions), with the rest occurring in the Efficiency and Efficacy (2 out of 7 questions), Coordination and Satisfaction and Learning dimensions (one question each). However, the positive response rate is less than 50% for two of these questions: Q21 and Q40. This means that even although students’ had a better perception of these aspects during the Hybrid semester, there is still room for improvement during future Hybrid semesters.

Out of the 30 remaining questions, the positive response rate for the Hybrid semester is lower than the one for the Virtual semester; however, it is usually higher than 70%. Dimensions like Communication, Coordination, Mutual support, and Satisfaction and Learning
5.2 Analysis

Within each semester. For each semester, we calculated Spearman’s correlation ($\rho$) between questions, in order to determine which aspects of teamwork quality were highly related for each course format. We used Spearman’s correlation since the questionnaire responses are in a Likert scale (ordinal data). Here, a strongly positive coefficient ($\rho \geq 0.8$) indicates that the Strongly Agree values of both questions tend to occur together, whereas a strongly negative coefficient indicates that the Strongly Agree values for one of the questions is apt to coincide with the Strongly Disagree values of the other question. A near-zero coefficient indicates that there is no relationship between the responses of the two questions being tested.

During the Virtual semester, we found strong positive correlations between the following questions:

1. Having spontaneous conversations ($Q_{34}$) and talking about topics not related to the project ($Q_{39}$), $\rho = 0.811$
2. Identifying with the team ($Q_{37}$) and talking about topics not related to the project ($Q_{39}$), $\rho = 0.814$
3. Developing good relationships ($Q_{36}$) and identifying with the team ($Q_{37}$), $\rho = 0.856$
4. Belonging to the team ($Q_{16}$) and feeling well integrated ($Q_{18}$), $\rho = 0.877$
5. Gaining technical know-how ($Q_{29}$) and domain-specific topics ($Q_{31}$), $\rho = 0.917$

Since we tested ($\frac{40}{1} = 780$ correlations, we adjusted the value of $\alpha$ using the Bonferroni method. The listed correlations are all statistically significant, with $p < 0.000064103$. The first three correlations are between questions about the course Mode, which was Virtual this semester. The fourth correlation is about team Cohesion, while the last one is about Satisfaction and Learning.

During the Hybrid 2022 semester, we found the following strong positive correlations between questions:

1. Completing major requirements ($Q_{19}$) and completing tasks in a timely manner ($Q_{23}$), $\rho = 0.805$
2. Understanding project goals ($Q_{4}$) and completing major requirements ($Q_{19}$), $\rho = 0.824$
3. Understanding project goals ($Q_{4}$) and being satisfied with the results of the project ($Q_{26}$), $\rho = 0.836$
4. Completing major requirements ($Q_{19}$) and being satisfied with the results of the project ($Q_{26}$), $\rho = 0.839$
5. Putting in as much effort as they could into the project ($Q_{14}$) and making a commitment to the project ($Q_{17}$), $\rho = 0.865$

These are also statistically significant, with $p < 0.000064103$. The correlated questions for this semester are associated to different dimensions of teamwork than in the virtual semester. The first and fourth correlations focus on different aspects of Efficiency and Efficacy, the second and third on the relation between Coordination, and Efficiency and Efficacy, and the last one between Coordination and Cohesion. We did not find any strong negative correlations for either semester.

Between semesters. We also studied the distribution of question responses between semesters, in order to identify aspects of teamwork that differed significantly. As such, we elaborated the following hypotheses, where $x = 1 \ldots 40$:

$H_5$: There is a difference in the distribution of $Q_x$ responses between semesters Virtual 2021 and Hybrid 2022. The corresponding null hypothesis $H_{50}$ is that the response distribution for both semesters is similar for $Q_x$. 

have generally positive responses both semesters ($\geq 67\%$). The dimension Balance of member contributions is mostly positive, with the exception being $Q_9$, which focuses on the technical know-how that team members bring to the project. The positive answer rate for this question in the Virtual semester was already lower than the other questions for this dimension (65% versus 75% or higher), and dropped to 48% during the Hybrid semester. In the case of Effort, $Q_{14}$ (individual effort) is much more negative during the Hybrid semester: only 44% of the Hybrid responses are positive, compared to 74% during the Virtual semester.

Cohesion was quite positively evaluated during the virtual semester ($\geq 84\%$) but only received 60-63% positive answers during the hybrid semester. The Efficiency and Efficacy dimension is similar to Balance of member contributions, where all but $Q_{21}$ got mostly positive responses ($\geq 75\%$). With respect to $Q_{21}$, during the Virtual semester, students perceived that the product needed much more work after the course ended, since only 22% of the responses were positive. However, during the Hybrid semester, the positive response rate increased to 44%, meaning that more students perceived their projects were completed by the end of the third iteration. The last dimension, Virtual/Hybrid mode, was also generally positive except for the last question $Q_{40}$, which asked students about the level of friendship that they perceived they reached with their teammates. Both semesters only had a 45-48% positive responses, and the Hybrid semester had a slightly higher rate of negative responses (25% versus 20%).

We also report the median for each question/semester in Table 3, shown in the corresponding column under the Median header. Since we are working with ordinal data, we use the median in order to analyze the central tendency for the questionnaire responses. We can observe that the medians for 36 questions are in the range [4, 5] in both semesters, meaning that 50% of the students have a positive perception about teamwork, independent of the course format. The exceptions are $Q_9$, $Q_{14}$, $Q_{21}$, and $Q_{40}$. In the case of $Q_9$ (enough technical know-how about the project in the team) and $Q_{14}$ (enough individual effort), the median went from 4 (Agree) during the Virtual semester, to 3 (Neutral) during the Hybrid semester. On the other hand, the median for $Q_{21}$ and $Q_{40}$ was 3 for both semesters. These two questions also had the lowest positive response rates.

In the same table, we have highlighted in green/red the Hybrid semester medians that were higher/lower than the Virtual semester. These changes are not uniformly spread out by dimension, with most of the negative differences occurring in dimensions Balance of member contribution, Effort and Cohesion. It is worth noting that this negative change in perception occurred even though the software development activities were carried out online during both semesters. Paradoxically, the only positive differences in median occurred in the Virtual/Hybrid mode dimension, meaning that students generally had a better perception of the course format during the Hybrid semester.
We ran Mann–Whitney U tests to check these hypotheses. We used this test because we are working with ordinal data and small sample sizes. We found significant differences in 15 questions, across 8 dimensions, as shown in Table 4. In the majority of these questions, the percentage of Strongly Agree answers was lower in the Hybrid semester than in the Virtual semester. The only exception was Q33, where the percentage of Strongly Agree answers increased, and the Agree, Neutral and Disagree answers decreased. In other words, students felt less isolated during the Hybrid semester, when compared to the Virtual one. The changes in the distribution of Q14 (individual effort) responses between semesters is also different: here we see that the percentage of both Strongly Agree and Agree answers decreased during the Hybrid semester, compensated by an increase in Neutral, Disagree and Strongly Disagree answers. In other words, students perceived that their teammates made less of an individual effort during the Hybrid semester.

For the remaining 13 questions, we see a similar change in the distribution of answers: the decrease in Strongly Agree answers is compensated by the increase in Agree, Neutral, Disagree and Strongly Disagree answers in the Hybrid semester. In the case of questions Q11, Q15, Q17, Q18, and Q27, we also see the appearance of Strongly Disagree answers in the Hybrid semester, which did not occur during the Virtual semester.

Table 4: Significant differences between semesters

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Question</th>
<th>U</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>Q1 - Frequency</td>
<td>130.30</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Q3 - Effectiveness</td>
<td>174.50</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Coordination</td>
<td>Q4 - Understand goals</td>
<td>322.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Balance of member contributions</td>
<td>Q5 - Contributes according to abilities</td>
<td>419.00</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Q8 - Free of conflict</td>
<td>308.50</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Q10 - Managerial knowledge</td>
<td>293.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Mutual support</td>
<td>Q11 - Peer support</td>
<td>235.50</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Q12 - Constructive conflict resolution</td>
<td>300.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Effort</td>
<td>Q14 - Individual effort</td>
<td>262.00</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Q15 - Effort to address challenges</td>
<td>276.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Cohesion</td>
<td>Q16 - Relevance of each member</td>
<td>246.00</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Q17 - Member commitment</td>
<td>215.50</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Q18 - Member integration</td>
<td>223.50</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Satisfaction and Learning</td>
<td>Q27 - Benefits of collaboration</td>
<td>314.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Virtual/Hybrid mode</td>
<td>Q33 - Isolated</td>
<td>279.00</td>
<td>0.01</td>
</tr>
</tbody>
</table>

6 DISCUSSION AND THREATS TO VALIDITY

We found differences in almost all dimensions of teamwork between the two semesters. Remarkably, the only aspect of teamwork that significantly improved in the hybrid format was Isolation. This result is supported by some of the comments that students included in the survey at the end of the Virtual 2021-2 semester. For example, one student stated: “Even though working virtually was fine, I think that some in-person meetings would have been helpful, so that we could work together with the client’s developers”. Another student said that “Working remotely by sharing screens is comfortable, but I think that it does not compare to working together, considering the informal moments that we could share that way”. Students also valued the instructor’s input: “we are grateful for the instructor’s support and advise”, and “the instructor is always rigorous, but is always also available to listen to us and give advice”. During the Hybrid 2022-1 semester, students did not comment about the course format in the survey. They only highlighted the success of the project, or they complained about particular teammates that did not show enough commitment to the project. They also complained about the excessive time they needed to dedicate to the course.

We hypothesize that these results are due to several intertwined circumstances. On the one hand, seclusion during the Virtual 2021-2 semester made students value interaction with their teammates and instructor support, but when they were able to attend other courses in-person during the 2022-1 semester, they had plenty of opportunities for socializing. Interaction within the team was no longer so highly valued. On the other hand, when Software Project and other courses started demanding in-person activities, the time required for working on the project started competing with other obligations, and thus it somehow became a burden, rather than a space to learn about teamwork.

Now we discuss the Threats to Validity of our study. Regarding construct validity: the survey includes teamwork dimensions proposed in the literature. However, these dimensions may not be so relevant in the context of our course, and we may be leaving out other dimensions that may be more relevant.

Regarding external validity: some of our results may only be valid for students from our country and/or university. Students’ experiences before the course, and the projects we select may have a big influence on their perceptions about the value of teamwork. However, the students in this course share most of the characteristics of students taking software engineering capstone courses.

Regarding internal validity: we compared the final Virtual semester with the first Hybrid semester. However, all activities had to be online during the Virtual semester, whereas we could pick and choose for the Hybrid semester. Moreover, perceptions of the value of teamwork during the Virtual semester may be biased, since students were also under stress due to the COVID-19 pandemic. Nevertheless, the results reported in this paper may be a valuable input for a future refinement of the Hybrid format of the course.

7 CONCLUSIONS

In this paper we analyzed the quality of teamwork of a software engineering capstone course when conducted in a the virtual form that was implemented due to the COVID-19 pandemic and a hybrid form resulting from adding some in-person activities that finally became possible in 2022.

To this end, we conducted a survey of students’ perceptions about teamwork quality in each semester. We found that students valued teamwork highly, as well as the sense of belonging that it provided during the semester that was completely virtual, but this was not the case any more during the hybrid semester. We hypothesize that this is because students addressed their needs for socializing with other activities, and not in the context of the project when it was finally possible.

There are many more situations that affect teamwork quality than we expected when redesigning the course. During the pandemic, students were used to optimizing their free time, since they did not need to commute to our campus or their client’s offices.
When in-person activities resumed, students tried to continue taking as many credits as they were taking during the pandemic, which resulted in poor academic performance, not only in our Software Project course.

We have seen that, as we begin to return to normality, students are facing courses with lower levels of anxiety. In particular, in the following semester, they voluntarily get together for working in-person although it was not required by the course. We think that this behavior will naturally address the lowest dimensions of both semesters studied: the isolation of the virtual format and the poor project management of the hybrid format of the course.

REFERENCES