Virtual vs. Hybrid Teamwork Quality in a Software Development Capstone Course

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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.

CCS CONCEPTS

• **General and reference → Empirical studies**; • **Software and its engineering → Collaboration in software development**; • **Social and professional topics → Software engineering education**.

KEYWORDS

capstone course, teamwork, virtual, hybrid

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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, extroversion, openness, agreeableness, and conscientiousness [9]. Team conformation may also affect teamwork [10]: team size, time availability, experience, motivation, experience and gender, among others.

According to Hoegl [12] and Lindsjør [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 can 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 1: Teamwork dimensions (from [1][12][13])

Communication	Frequency
	Effectiveness
Coordination	Free of conflict
	Understand goals
	Share goals
Balance of member contribution	Strengths and weaknesses
	Contributes according to their abilities
	Free of conflict
	Technical knowledge
	Managerial knowledge
Mutual support	Peer support
	Constructive conflict resolution
	Reaching consensus on relevant issues
Effort	Individual effort
	Enough effort to address challenges
Cohesion	Relevance of each member
	Member commitment
	Member integration
Efficiency and Efficacy	Completed requirements
	Satisfaction
	No extra work required
	Project success
	Tasks finished in the expected time
	Main requirements finished in each iteration
	No extra working time required
Satisfaction and Learning	Willingness to work on similar projects
	Benefits of collaboration
	Simultaneous work
	Technical knowledge gained
	Managerial knowledge gained
	Domain-specific knowledge gained
Virtual/Hybrid mode	Easy to contact teammates
	Isolation
	Informal conversation
	High team performance
	Positive teammates relationship
	Team integration
	Comfort
	Talk about topics unrelated to the project
	Gain new friends

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 form 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

Semester	# Students	# Responses	Response Rate
Virtual 2021-2	58	31	53%
Hybrid 2022-1	44	27	61%

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.

Table 3: Distribution of responses per question and semester

Id	Questions	Virtual 2021-2					Hybrid 2022-1					%P		Median	
		SD	D	N	A	SA	SD	D	N	A	SA	V	H	V	H
	Communication														
Q_1	Communication with the team was frequent	0	0	1	3	27	0	0	6	16	5	97	78	5	4
Q_2	Communication with the team was effective	0	0	2	8	21	0	1	5	18	3	94	78	5	4
	Coordination														
Q_3	The organization of each task was conflict-free	0	1	3	8	19	0	0	2	13	12	87	93	5	4
Q_4	The team understood the goals of the project	0	1	1	6	23	0	2	2	9	14	94	85	5	5
Q_5	The goals of each task were shared by all team members	0	2	4	10	15	0	3	3	11	10	81	78	4	4
	Balance of member contributions														
Q_6	The team recognizes the strengths and weaknesses of each member	0	1	4	14	12	0	2	4	9	12	84	78	4	4
Q_7	Team members contributed to tasks according to their strengths and weaknesses	1	1	1	10	18	1	2	3	11	10	90	78	5	4
Q_8	Few or no conflicts occurred given the imbalance of contributions	0	2	1	10	18	0	6	1	10	10	90	74	5	4
Q_9	Within the team there was technical knowledge related to the project	1	3	7	11	9	0	9	5	4	9	65	48	4	3
Q_{10}	The team had the necessary skills to manage the project	0	1	2	8	20	0	4	2	11	10	90	78	5	4
	Mutual support														
Q_{11}	The team members supported each other in the best way	0	0	1	6	24	1	2	3	11	10	97	78	5	4
Q_{12}	If conflicts arose, they were resolved constructively	0	0	1	6	24	0	1	4	8	14	97	81	5	5
Q_{13}	The team was able to reach consensus on important decisions	0	0	1	4	26	0	1	0	8	18	97	96	5	5
	Effort														
Q_{14}	Each team member put in as much effort as they could into the project	0	4	4	10	13	1	6	8	8	4	74	44	4	3
Q_{15}	Each member's effort was sufficient to solve problems with the technologies used	0	2	0	9	20	0	3	3	12	9	94	78	5	4
	Cohesion														
Q_{16}	For each member it was important to belong to the team	0	1	4	9	17	1	3	6	12	5	84	63	5	4
Q_{17}	Each member was committed to the project	0	2	3	6	20	1	5	5	11	5	84	59	5	4
Q_{18}	Each member was well integrated into the team	0	2	1	9	19	1	7	2	11	6	90	63	5	4
	Efficiency and Efficacy														
Q_{19}	Major requirements completed	0	0	0	9	22	0	0	0	10	17	100	100	5	5
Q_{20}	The team is satisfied with the project results	0	0	1	6	24	0	1	0	9	17	97	96	5	5
Q_{21}	The product does not require further work	1	12	11	5	2	2	9	4	6	6	23	44	3	3
Q_{22}	The team considers the project a success	0	0	0	11	20	0	1	0	9	17	100	96	5	5
Q_{23}	Tasks were completed in a timely manner	0	0	4	10	17	0	4	0	9	14	87	85	5	5
Q_{24}	The main requirements were ready at the end of each iteration	0	0	4	10	17	0	0	2	7	18	87	93	5	5
Q_{25}	The project did not require more hours than the course requirement	0	2	6	7	16	0	5	3	7	12	94	70	5	4
	Satisfaction and Learning														
Q_{26}	Would you work on a similar project in future?	1	1	6	10	13	6	0	3	8	10	74	67	4	4
Q_{27}	You benefited from working collaboratively on this project	0	0	2	7	22	2	4	1	6	14	94	74	5	5
Q_{28}	Working simultaneously contributed to the development of the project	0	2	0	8	21	0	3	4	4	16	94	74	5	5
Q_{29}	You gained considerable technical know-how during the project	0	2	5	4	20	2	2	5	5	13	77	67	5	4
Q_{30}	You learned important lessons about project management	0	2	2	9	15	1	1	2	10	13	86	85	4	4
Q_{31}	You learned a lot about a domain-specific topic related to the project	0	0	7	5	19	0	1	1	11	14	77	93	5	5
	Virtual/Hybrid mode														
Q_{32}	The work mode allows me to easily contact my teammates	0	0	2	14	15	1	1	0	6	19	94	93	4	5
Q_{33}	I do not feel isolated in this work mode	0	8	3	8	12	1	1	2	4	19	65	85	4	5
Q_{34}	The work mode allows for spontaneous, informal conversations	1	2	7	10	11	1	1	5	6	14	68	74	4	5
Q_{35}	The work mode enables a good team performance	0	0	5	11	15	0	0	6	6	15	84	78	4	5
Q_{36}	The work mode enables me to develop good relationships with the team	0	2	10	7	12	0	3	6	9	9	61	67	4	4
Q_{37}	The work mode enables me to identify myself with the team	0	4	7	9	11	1	1	5	8	12	65	74	4	4
Q_{38}	I feel comfortable in this work mode	0	4	4	6	17	1	0	1	7	18	74	93	5	5
Q_{39}	This work mode allows me to talk about topics not related to the project	2	2	5	12	10	1	3	4	8	11	71	70	4	4
Q_{40}	The work mode allows me to create friendships with my teammates	2	4	11	7	7	1	6	7	6	7	45	48	3	3

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: Q_{21} and Q_{40}. 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*

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.

5.2 Analysis

Within each semester. For each semester, we calculated Spearman's correlation (ρ) 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 $\binom{40}{2} = 780$ correlations, we adjusted the value of α 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_{20}), $\rho = 0.836$
(4) Completing major requirements (Q_{19}) and being satisfied with the results of the project (Q_{20}), $\rho = 0.839$
(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_x: There is a difference in the distribution of Q_x responses between semesters Virtual 2021 and Hybrid 2022.
The corresponding null hypothesis H_{x0} is that the response distribution for both semesters are similar for Q_x.

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 Q_{33}, 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 Q_{14} (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 Q_{11}, Q_{16}, Q_{17}, Q_{18}, and Q_{27}, 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

Dimension	Question	U	p
Communication	Q_1 - Frequency	130.50	< 0.05
	Q_2 - Effectiveness	174.50	< 0.05
Coordination	Q_4 - Understand goals	322.00	0.04
Balance of member contributions	Q_7 - Contributes according to abilities	319.00	0.05
	Q_8 - Free of conflict	308.50	0.03
	Q_{10} - Managerial knowledge	293.00	0.02
Mutual support	Q_{11} - Peer support	235.50	< 0.05
	Q_{12} - Constructive conflict resolution	300.00	0.01
Effort	Q_{14} - Individual effort	262.00	0.01
	Q_{15} - Effort to address challenges	276.00	0.01
Cohesion	Q_{16} - Relevance of each member	246.00	< 0.05
	Q_{17} - Member commitment	215.50	< 0.05
	Q_{18} - Member integration	223.50	< 0.05
Satisfaction and Learning	Q_{27} - Benefits of collaboration	314.00	0.03
Virtual/Hybrid mode	Q_{33} - Isolated	279.00	0.01

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 discus 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.

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