

# A Case Study of Teamwork and Project Success in a Comprehensive Capstone Course

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**Abstract.** Teamwork is essential in agile software development projects. Therefore, software engineering students who participate in a software engineering capstone course involving teamwork are better prepared for the industry. This study investigated student teams over three years in a comprehensive capstone course offered by the University of Oslo. The collaboration between the students involved in the course changed from in person in 2019 to virtual in 2020 and 2021 due to the COVID-19 pandemic. In this study, we aimed to explore the differences in teamwork and the effect on project success when the student teams collaborated in person versus virtually. A mixed-methods case study was conducted. The quantitative data consisted of surveys representing 126 student teams and 595 individual respondents. The qualitative data included eight semi-structured interviews. The results indicate that the student teams in such software engineering capstone courses perform well even when collaborating virtually, but they are less satisfied than they are when in person. The student teams found it hard to motivate themselves when they suddenly had to work virtually. Still, the motivation increased when they found ways to collaborate and make the project case exciting. The teams found adequate collaboration tools and managed to carry out the teamwork virtually. Even though it was harder to work virtually, project success was not significantly affected. The student teams that performed well also used virtual collaboration proficiently.

**Keywords:** Teamwork, Team Performance, Agile Development, Software Engineering Education, COVID-19, Coordination, Communication, Virtual Collaboration

## 1 Introduction

To reduce the skill gap between graduating students and industry expectations, the use of capstone courses in higher education software engineering has increased over the last few decades [1, 2]. In software engineering capstone courses, the students often deal with real problems similar to those they face in the industry [3]. The general findings on software engineering capstone courses are that they provide students with desirable knowledge and experiences that will be helpful later in their careers. Teamwork and industry involvement are essential aspects that students experience in capstone courses [4]. Recently, Stålhane et al. [5] found that software companies that hire graduate students look for programming knowledge, the willingness to learn new things, and communication skills. These aspects are essential in most software engineering capstone courses, especially communication. Good communication skills are crucial

when working in software teams [6]. Most software engineering capstone courses make students participate in teamwork that many of them have never experienced before.

Starting as a pilot course in 2018 with four teams, the University of Oslo offers a 20 ECTS software engineering capstone course in which the students work on a project in teams of five to seven students. The teams are put together by the instructors, but the students suggest one to three peers they want to have on their team (a discussion of team formation in this course can be found in [7]).

The number of students has grown: 200 students in 2019 (39 teams), 240 students in 2020 (42 teams), and 280 students in 2021 (48 teams). The students work in agile teams and develop a mobile weather app on the Android platform using data from the Norwegian Meteorological Institute's API<sup>1</sup>. At the end of the project period, the student teams deliver the source code of the project and a written report. The source code and the written report combined counts for 50% of the final grade in the course. In addition, the students have an individual written exam at the end of the semester, which also counts for 50% of the grade. Due to the sudden lockdown in spring 2020, the grade became pass/not pass for both project and exam.

Some research conducted on teamwork in software engineering capstone courses has reported that students are better prepared for the industry after participating in a capstone course [1–3]. Therefore, this aspect is also essential in this course; one of the main objectives is to prepare the students to work as they would in real life. The teams use agile methods and practices and experience relevant aspects of software development work, such as requirement collection and analysis, design, programming, testing, and maintenance. The students participate in teamwork and deal with requirements from a real customer.

During the project work in the spring of 2020, the teamwork became virtual overnight due to the COVID-19 virus. The students had to adapt to the new work environment and use tools to collaborate virtually. Naturally, research on student teams adapting their workday from collaborating in person to suddenly working remotely from home has been sparse. This paper investigates the way the collaboration within student teams in a software engineering course changed and the consequences when the teams went from working in person to working solely via online meetings and interactions. The research question is as follows: *What were the differences in teamwork and the effects on project success when the student teams collaborated in person versus virtually?*

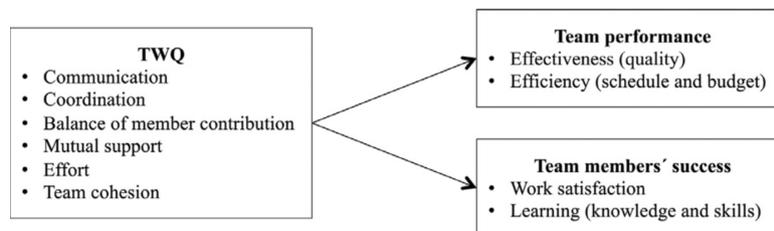
To answer the question, we conducted a survey on teamwork quality (TWQ) and the relationship to project success for all the teams in the course from 2019 (working physically), 2020 (working both physically and virtually), and 2021 (working virtually). In addition, in 2020 and 2021, we added questions regarding virtual collaboration. Interviews (mainly with students involved in the course in 2020) and observations were also part of the study.

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<sup>1</sup> <https://api.met.no/>

## 2 Team Performance

Team performance and team effectiveness are often used synonymously in the literature; sometimes, team performance is part of team effectiveness (e.g., Cohen and Bailey [8]). Sometimes, team effectiveness is part of team performance (e.g., Hoegl and Gemuenden [9]). However, most of the models of team performance (or team effectiveness) originate from management science and psychology [10]. The input-process-outcome (IPO) model is a framework for studying team performance (or team effectiveness) and was initially conceptualized in 1964 [11]. The IPO model has served as a foundation of TWQ models for researchers over the years [12]. Two of the most used team performance models are the Big Five model [10] and the TWQ model [9, 13]. Since we have used the TWQ model (Fig. 1) in studies on professional teams [13, 14], we also used the TWQ model for this study comparison.



**Fig. 1.** The TWQ model and the effect on team performance and team members' success. Derived from Lindsjorn et al. [13], and initially developed by Hoegl and Gemuenden [9].

In addition to the TWQ model, we used the Sociability Scale conceptualized by Kreijns et al. [15] to measure the ways in which the students perceived the virtual environment when collaborating digitally. The concept of *sociability* is to what extent students perceive that a computer-supported collaborative learning environment facilitates sound learning outcomes [15]. Some key attributes of the concept of sociability are trust within the team, belonging, and relationship.

## 3 Method

We chose to conduct a multiple-case study, exploring and comparing data for the three semesters 2019, 2020, and 2021 (see Table 1). Multiple-case design supports replication, predicting the production of either similar or contrasting results (Yin, 2009). We gathered both qualitative and quantitative data. Combining qualitative and quantitative methods, also referred to as mixed-method design [16, 17], may help to improve the understanding of the investigated phenomenon [18].

The student survey consisted of 91 items, including ten items measuring sociability (virtual learning environment) and 61 items measuring TWQ and project success. In addition, 20 items related to tools they used and background items such as gender and age, study program, and previous experience in agile development.

**Table 1.** Number of respondents for each of the surveys

Semester	2019	2020	2021
Number of students	201	240	281
Number of teams	39	42	48
Respondents	198	151	246
Response rate (%)	98.5	62.9	87.5
PO respondents	5	9	10

The TWQ survey consisted of a questionnaire to which the respondents answered 61 items on a Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). There were three different respondent groups (raters): team members, team leaders, and product owners (POs). The PO role was represented by student assistants supervising the teams. The surveys were conducted shortly before or shortly after delivering the project. In 2019, the survey was answered physically on paper, whereas in 2020 and 2021, the teams answered the surveys digitally. The Sociability Scale was used in 2020 and 2021. All the data from the surveys were analyzed using SPSS version 2.7 and Python scripts.

Semi-structured interviews have a set of predetermined questions to be answered, but the interviewer might sometimes deviate from the predetermined questions [17]. In the spring of 2021, eight semi-structured interviews were conducted online, using the digital tool Zoom. Seven of the interviewees had completed IN2000 in 2020, of whom six were student assistants in 2021. One of the interviewees was a representative from the Norwegian Meteorological Institute. The interviews were recorded and transcribed. NVivo 12 was used for analysis.

## 4 Results

### 4.1 Descriptive Statistics from the Surveys

Table 2 shows the descriptive statistics for the TWQ survey for all the investigated semesters with mean values and standard deviations (SD) for all the constructs in the TWQ model. All results are aggregated on the team level. The results are relatively similar for all semesters. The mean values of the TWQ variables are somewhat higher in 2021 compared to both 2020 and 2019. The 2020 semester overall has the

**Table 2.** Descriptive statistics of TWQ surveys in all three semesters aggregated on team level

Construct	Rater/role	Variable	No. items	2019		2020		2021	
				Mean	SD	Mean	SD	Mean	SD
Team Quality (TWQ)	Team member	Communication	10	4.17	0.37	3.99	0.51	4.15	0.35
		Coordination	4	4.05	0.40	3.98	0.45	4.14	0.33
		Mutual support	7	4.42	0.37	4.33	0.47	4.50	0.33
		Cohesion	10	4.26	0.45	4.20	0.45	4.37	0.37
		Effort	4	3.86	0.65	3.73	0.62	3.97	0.53
		Balance of contribution	3	4.25	0.41	4.24	0.50	4.32	0.46
Team members' success	Team member	Work satisfaction	4	4.28	0.44	4.37	0.40	4.41	0.43
		Learning	4	4.41	0.47	4.42	0.45	4.55	0.31
Team performance	Team member	Effectiveness TM	10	3.86	0.42	4.03	0.34	4.07	0.42
		Efficiency TM	5	3.81	0.60	3.98	0.55	4.07	0.51
	Team leader	Effectiveness TL	10	3.83	0.65	4.30	0.54	4.15	0.58
		Efficiency TL	5	3.83	0.74	4.20	0.75	4.12	0.72
	Product owner	Effectiveness PO	10	3.90	0.72	4.07	0.56	4.11	0.63
		Efficiency PO	5	3.71	0.87	3.92	0.73	4.12	0.72

**Table 3.** Descriptive statistics of the sociability items in 2020 and 2021 on individual level

Item	2020		2021	
	Mean	SD	Mean	SD
The virtual learning environment enables me to easily contact my teammates	3.90	0.83	3.90	0.66
I do not feel lonely in the virtual learning environment	3.65	0.78	3.58	0.71
The virtual learning environment enables me to get a good impression of my teammates	3.31	0.75	3.38	0.72
The virtual learning environment allows spontaneous informal conversations	3.57	0.89	3.45	0.75
The virtual learning environment enables us to develop into a well performing team	3.54	0.70	3.67	0.64
The virtual learning environment enables me to develop good work relationships with my teammates	3.48	0.70	3.48	0.69
This virtual learning environment enables me to identify myself with the team	3.52	0.67	3.45	0.62
I feel comfortable in the virtual learning environment	3.86	0.73	3.95	0.56
The virtual learning environment allows for non-task-related conversations	3.37	1.00	3.33	0.81
The virtual learning environment enables me to make close friendships with my teammates	2.73	1.00	2.70	0.76

lowest evaluation of all the TWQ variables. Taking a closer look at, for example, communication, we can see that it dropped (-0.18) from 2019 to 2020 but increased (+0.16) from 2020 to 2021. The mean value of learning was very similar in 2019 and 2020 but increased from 2020 to 2021 (+0.13). Effectiveness under team performance was significantly higher in 2020 than it was in 2019 (+0.17) and even higher in 2021 (+0.03).

The students' evaluation of all variables was perceived higher it was than in 2020 and 2019, except communication. The SD is also significantly lower in 2021 overall compared to the other semesters for all variables.

The mean values of team members' evaluation for TWQ were 4.17, 4.08, and 4.24 in 2019, 2020, and 2021 respectively. Further, the mean values under project success were 4.09 in 2019, 4.20 in 2020, and 4.28 in 2021.

From Table 4, we see that the results are relatively similar for both semesters on all items. However, because Item 10 on the Sociability Scale was evaluated significantly lower than any other item, this aspect was further investigated during the interviews.

## 4.2 The Effect of TWQ on Project Success

Fig. 2 shows the effect of TWQ on the dependent variables for each of the investigated semesters. The effect of TWQ on team members' success was significantly higher in 2019 than it was in 2020 and 2021. The team member perception of team performance was slightly higher in 2021 than it was in 2019 and 2020. Looking at the team leaders' perceptions of team performance, we can see that in 2021, it was significantly higher. The POs (teaching assistants) perceived team performance equally in 2019 and 2020 and lower in 2019.

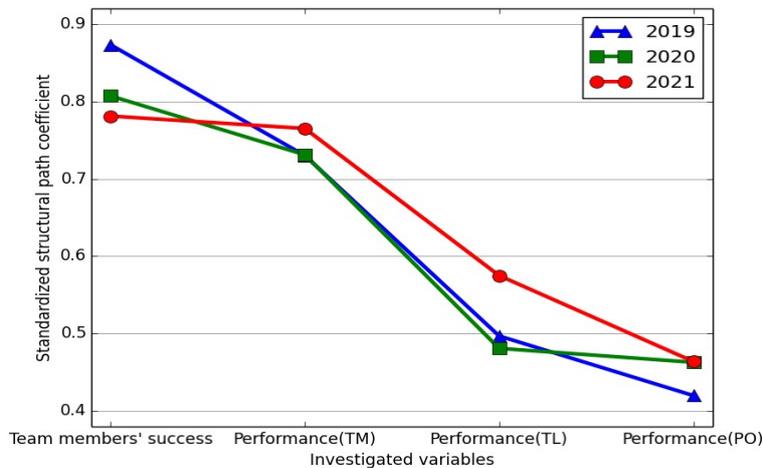


Fig. 2. Standardized path coefficients from TWQ variables to the four dependent variables.

## 4.3 Interviews

*Communication.* Communication was regarded as most important by the respondents and had the highest amount of NVivo coding. One student expressed that poor communication resulted from the lack of physical presence at the campus:

“I feel like there were two completely different worlds: before the lockdown and after the lockdown. When we physically met at the campus, we maintained good communication and communicated using Slack between the physical meetings. However, after the lockdown, we only used Slack, and the communication became slow and sporadic.”

One student emphasized that the meetings became more formal, causing informal communication to vanish: “Before the lockdown, the social aspects were good as we could talk before and after the meetings. However, after COVID-19 hit, we had to carry out meetings on Zoom, and the meetings suddenly became way more formal. When turning on the laptop camera, we only worked with the project, and we never had any breaks where we just talked like we usually would if we could physically meet.” Another student emphasized something similar: “I think I would have known the others better if there were physical collaboration throughout the semester. In the beginning,

when we met physically, we discussed and got to know each other. It is easier to joke and get to know each other in the same room than in a formal chat.”

One respondent expressed that the threshold of asking for help increased due to the lockdown: “I felt like the threshold of asking teammates for help grew. I did not want to disrupt others with minor problems, and in the beginning, starting a Zoom meeting to solve a problem was a quirk. I think the teamwork would have been better if the threshold for reaching out to teammates was lower.” One interviewee did not find making friendship relevant because all team members knew each other already. However, the student expressed they missed working with other students: “I missed working with students I did not know from before.”

*Motivation.* The team members’ motivation was a significant factor in the degree to which the teams performed successfully. During the presentations of the projects in 2020, all the teams were asked the same question: “How did the coronavirus situation (i.e., closing down the campus) and the fact that the grade was only pass/not pass influence your motivation in the course?” The most common reply was along the lines of, “The motivation became lower at once, but when we started to work together as a team, we wanted to make a good app, write a good report and learn how to use some agile practices during the teamwork, the motivation came back.”

All interviewees reported that the motivation dropped after the lockdown in the 2020 semester. There was no one particular reason why the motivation dropped. However, some interviewees mentioned that changing grades from A to F to pass/not pass was the main reason: “It was demotivating when the grades changed since we knew our product was sufficient. We were less motivated to work with the course, and as a result, I think we ended up putting in less effort than we usually would if the grade had not changed.”

Even though the motivation dropped at first, most of the students increased their motivation throughout their work on the project. Most students reported that their chosen project case was engaging during the presentations, which boosted their motivation. One interviewed student pointed out that the motivation increased because they wanted to make the best out of the situation: “The team members agreed that we should do the best we can, even if there are no letter grades anymore. (...) If we put in enough effort, we will still have a great outcome of this course; we can show the product during job interviews. The motivation rose when we changed the mental focus from grade to personal gain.” Some students still pointed out that they could not recover from the drop in motivation: “I felt like the motivation was low throughout the project period after the lockdown. It became harder to motivate oneself to work with the course. Even though we never stopped having meetings and produced code, I felt like the drive was gone. (...) The team never discussed how we could raise the motivation. We just accepted the fact that this is how the course is going to be.”

*Using collaboration tools.* During the interviews, most respondents underlined that combining tools was beneficial: One of them stated: “We mainly used Slack, Zoom, and Google Drive. We did not want to use Facebook to separate work and spare time. Therefore, we used Slack for messaging, Zoom for meetings, and Google Drive for

sharing files. Slack was nice since we could create specific channels regarding the different aspects of the project.”

One respondent emphasized they used tools to communicate, often orally instead of typing in a chat:

“We ended up using Discord because of voice channels. We found it helpful to have a platform to quickly ‘jump’ in and out of rooms in this project. We spent much time talking, and we did not write a lot of messages. So, having the voice channels of Discord aided our teamwork.” Another respondent expressed their team was not able to utilize the tools fully: “It was hard to relate to Trello. Therefore, Trello was not prioritized, and we had a messy backlog. We mostly used Slack to discuss which tasks to choose, but as we decided on tasks, we did not update the board in Trello. (...) We never scheduled meetings. We just randomly met on Zoom from time to time. I feel like finding timeslots and breaking the ice using the tools was hard.”

Most teams used some combination of multiple tools. The most popular tool in 2020 was Slack, which often was combined with Zoom. In 2021, Zoom and Trello were the two most popular. Student teams that utilized the functionality of the tools performed better overall compared to those that did not. Using digital collaboration tools was essential to facilitating teamwork. Without the collaboration tools, virtual teamwork would nearly be impossible.

## 5 Discussion

This section will discuss the results. The main research question was as follows: What were the differences in teamwork and the effect on project success when the student teams collaborated in person versus virtually? Though some differences were found, the findings show that the effect of TWQ on project success did not drop significantly in 2020 through the shutdown of campus. We discuss possible reasons for the findings concerning both the descriptive statistics of TWQ and project success and the effect of TWQ on project success for all three semesters. We also look at the following collaboration aspects: communication, motivation, tools, and the Sociability Scale.

### 5.1 TWQ and Project Success

The investigated semesters’ descriptive statistics were relatively equal (see Table 2). There was a notable decrease of all items in 2020 compared to the other semesters. One reason the students perceived their teamwork as worse in the 2020 semester compared to the 2021 semester might be a result of the direct effects caused by the lockdown. We found it interesting that the students’ perception of nearly all the TWQ variables was higher in 2021 than it was in the other semesters.

Comparing the descriptive statistics of this study to the study conducted on professional teams [13], the mean values of the student teams were slightly higher in all investigated semesters than were the values of the study of professional teams, except effort which was the only variable evaluated higher in professional teams. The industry

has a more explicit facilitator role for daily stand-up and other meetings, and a more dedicated PO role might explain this.

Fig. 2 shows the effect of TWQ on the four dependent variables. The effect of TWQ on team members' success was higher in 2019 than it was in both 2020 and 2021. An apparent reason is that the teamwork was conducted in person at the campus in 2019. The team member perception of team performance was slightly higher in 2021 than it was in 2019 and 2020. Overall, the effect of TWQ on project success (team member success and team performance combined) as rated by the team members was high in all semesters. The team leaders' (scrum masters) perceptions of team performance were significantly higher in 2021. One explanation might be because the students who perceived their role as team leaders were closer to their teams this year.

The POs (teaching assistants in this course) perceived team performance as almost equal in 2020 and 2021, whereas it was lower in 2019. The effect of TWQ on team performance as evaluated by the POs was the weakest among all the raters/roles. A reason for this might be that the PO role is the most distant from the teamwork [13].

The quality of the developed products did not decrease during the 2020 and 2021 semesters compared to 2019. One reason could be that during these semesters, the students were given a more thorough introduction to the course's technical aspects. Compared to 2019, the students had three additional lectures on the technical aspects: Android Studio, Kotlin, and the API from Norwegian Meteorological Institute. In addition, the students had to deliver an extra mandatory assignment. As a result, the students had a better precondition in 2020 and 2021 than they did in 2019 regarding the technical aspects. In addition, improving other teaching activities in 2020, such as introducing a kickoff event, had an effect. Furthermore, in 2021, the students were more used to working virtually. Therefore, a combination of consistency and clear guidelines from the university made the semester more reliable than it was 2020. In addition, as the students were used to working digitally from the previous semesters, they did not have to adapt to a changed work situation mid-project as they did in 2020.

## 5.2 Communication

Communication processes in student teams changed when working virtually during the pandemic, for example, some teams reported having more difficult communication, and some reported having more efficient communication. [19]. In our research, the threshold for asking team members for help increased due to the lockdown. One interviewee mentioned that it was harder to ask ad hoc questions because they did not want to bother the others too much. Another interviewee also expressed that they did not want to disturb the team members when they were stuck on minor problems, hence they did not reach out to them. Other research conducted on software engineering capstone courses also reports the same finding. For example, Raaen et al. [20] reported that due to a lack of communication, the students in their capstone course felt a higher threshold for asking for help. Not asking fellow team members for help can result in much idle time, which means tasks can be delayed or not finished at all. One reason some students reported that the threshold for asking for help increased might be that they were not used to working in a virtual environment. They applied collaboration tools to support

their teamwork, but when the interactions became virtual instead of physical, it became harder to ask for help. Some mentioned they felt they were disrupting the other teammates when they asked for help. Another reason could be the absence of a distinct team leader (or coach), resulting in teams having no one taking the initiative to advance teamwork. Another finding from the 2020 semester is that the teams that met physically before the lockdown or participated in the kickoff event were more optimistic regarding teamwork than those that did not. Thus, having informal interactions and communication between team members is essential in agile software development and enhances the quality of the teamwork [21, 22].

### 5.3 Motivation

The motivation was a huge factor regarding how well the student teams performed. Teams that were unmotivated found it hard to collaborate, hence making the teamwork worse. As the surveys did not directly measure motivation (only indirectly in some questions of the TWQ construct cohesion), it is hard to compare motivation between the investigated semesters. The interviews, however, addressed motivation in more depth. For example, in the project presentations in 2020, the students reported that the motivation was lower in the 2020 semester when the lockdown occurred. The students were unfamiliar with working in teams virtually and using digital collaboration tools. Another factor that affected the motivation negatively was the change in grade from A to F to pass/not pass.

A recent study with data collected during the lockdown, reports that lack of motivation on an individual level negatively affected teamwork [23]. The findings show that the direct consequence of worse collaboration in student teams resulted in worse product development outcomes [23]. Our findings, however, suggest that even though the motivation dropped immediately after the lockdown, the motivation returned, and the quality of the products did not decrease. The student teams focused on the learning outcomes and personal gain of putting in an effort. As reported by interviewees and during the student presentation, having engaging cases with which to work was also a factor. Another study reports that when the students in their capstone project suddenly had to work remotely due to the lockdown, the team members' collaboration was negatively affected [20]. Our findings suggest that well-performing student teams working virtually were good at adapting to the sudden changes caused by the lockdown. Student teams that had a more "agile mindset" going into the course could better adapt and accomplished the virtual teamwork well.

### 5.4 Sociability: Friends or colleagues?

Yu et al. [24] reported that students find ways to reach out to each other by using online social networking facilities to organize activities to promote learning and communication as well as establish a bond between team members. Student teams able to do such activities overall report that the teamwork was fun, resulting in better performance [24]. In our study, from the results on the Sociability Scale (Table 3), we see that the evaluation of the item "making close friendship with team members" was significantly lower

than the other items were. Further, the respondents in the interviews expressed that making friends virtually is more challenging than doing so in person. Kreijns [15] also reported that “making friendship” scored the lowest among the participants. Even though the students could not establish close friendships in the virtual environment, the teams were still able to perform well, suggesting that a sense of community within the teams seems to be more important than friendship is.

## 5.5 Tools

Proficient use of collaboration tools is crucial when working virtually [25]. The results showed that teams able to utilize tools to their benefit performed better than teams that did not. There was no one specific ‘go-to’ tool but rather a combination of tools. The student teams were overall able to find suitable tools to carry out the teamwork virtually. Most respondents said they used some form of collaboration tools, either Slack or Discord, in either year. Trello was significantly more prevalent in 2021 compared to 2020. One reason for this could be that many teams visualized tasks on a board, which they then expressed during the presentations in 2021. Some teams reported that using tools for the sake of it was not beneficial and that teams must carefully select a few tools that suit their teamwork. When using too many tools at once, it was hard to keep all tools up-to-date.

## 5.6 Implications for Theory

The TWQ construct and the relation to project success has previously proven to be suitable for measuring TWQ and its effect on project success, both in traditional development [9] and agile [13, 14]. The concepts of TWQ and project success also worked well in this study. However, one discovery was that the attribute of efficiency, a part of team performance, did not seem to be very important in student teams. *Efficiency* refers to whether the teams met project quality expectations, such as time and cost [13]. The students had to deliver within the deadline, but otherwise, there were no formal requirements regarding the project quality. For example, they did not need to think of a budget. Therefore, when using the TWQ model on student teams in the future, one might consider removing the efficiency attribute.

Further, the Sociability Scale worked well for student teams. However, it is worth noting that when using the Sociability Scale, the Cronbach alpha values for 2020 and 2021 were unsatisfactory (0.94 and 0.95, respectively). Having such high alpha values on multiple data sets might hint that some of the Sociability Scale items are redundant.

## 5.7 Implications for practice

The students should be given a thorough introduction to the valuable tools that help increase the quality of interactions between the team members. Many teams used suboptimal tools. Having a lecture, seminar, or workshop where various tools are demonstrated (e.g., Slack) would be beneficial, even if the teamwork were to be carried out in person in the future. The students and teaching assistants reported the kickoff

event offered in the course was a success, so having more than one event that gathers the student teams could be a valuable addition to the course. Further, the student teams should have a fixed number of mandatory meetings with their supervisor throughout the project work to make sure they are working together satisfactorily and to help speed up the rate at which they overcome obstacles.

### **5.8 Limitations**

The interviews with the students were conducted nearly a year after they finished their projects (they delivered in May 2020; interviews were conducted in February/March 2021). Therefore, some respondents stated they did not remember the answers to some of the questions very well. As the team leader role is not directly transferable to the students' teams, some assumptions were made in the data collection. During the surveys, the respondents evaluated (on a scale from 1 to 5) the degree to which they were the team's scrum master/team leader. The students that rated their role as the scrum master/team leader the highest were selected as the team leader in the data set. The survey data gathered in 2020 had a lower response rate than the two other semesters had. In 2020, the students were not "forced" to answer as they were in 2019 and 2021. In 2020, the students responded digitally by e-mail after the semester had ended. This resulted in many fewer responses.

## **6 Conclusion**

A case study consisting of surveys and interviews has been conducted on a software engineering capstone course. The investigated semesters were 2019, 2020, and 2021. In 2019, the teamwork was carried out in person; all teaching and team activities were conducted on campus with all team members present. In 2020, the teamwork began in person at the campus but became digital in the middle of the semester. Finally, in 2021, all the teamwork was carried out digitally. An essential part of this study has been the comprehensive surveys measuring TWQ and the effect on project success for all three semesters.

The results showed a positive relationship between the evaluation of TWQ and project success for all three rater groups (team member, team leader, and PO). The results were similar for all three years, except the relationship between TWQ and team member success with a higher value in 2019 when the student teams collaborated in person. The mean values of all of the TWQ factors as well as team performance and team member success factors were also similar in the surveys for all three years, except communication, which was evaluated higher in 2019. The results indicate that student teams in a software engineering capstone course such as the one in this study perform well (the team performance is similar for all three years) though they collaborate virtually. Though their motivation decreased when the campus suddenly closed in 2020, the students' motivation increased again for most teams as they worked on the project. The fact that the effect of TWQ on team members' success (satisfaction and learning) was higher in 2019 indicates that the students prefer to meet in person and that they missed

the social life with the other students during the COVID-19 pandemic. Both the interviews and evaluation of the Sociability Scale support this conclusion; the students seemed to manage to work and collaborate virtually, but it was not easy to make new friends.

Most teams used several collaboration tools to facilitate their virtual teamwork. As a result, well-performing student teams understood that the tools could effectively benefit the teamwork. In particular, they integrated data between the different tools – both freely selected tools (e.g., Slack and Trello) and tools they were required to use (e.g., GitHub and Android Studio).

## 6.1 Future work

Changing the teaching assistant’s role from being a product owner (PO) into a facilitator role (team leader, coach) is recommended for future work. The PO role should be closer to that of professional teams where the PO role represents the customer and works with the backlog. Implementing this change would make the basis of comparison between student teams and professional teams more reliable. In addition, investigating the Sociability Scale used in 2020 and 2021 would be interesting. Future work could revise the Sociability Scale and explore which instrument items should be rephrased or removed. It would also be interesting to investigate the teams with the lowest and highest perception of TWQ and team performance to discover the “best” and “worst” teams regarding their teamwork.

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