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Post-Pandemic Hybrid Curriculum Recommendations for an Undergraduate ICT Senior Project Course*

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Among the numerous aspects of everyday life affected by the COVID-19 pandemic, education stands out as one of those deeply impacted. In this context within university settings, the ICT senior project courses were no exception either. This study presents the recommendations for a hybrid curriculum based on the online implementation of a senior project course in the ICT departments of an engineering faculty. The data were collected to better understand the impact of this re-structured course on 99 undergraduate IT students and their projects during three semesters, and later analyzed qualitatively and quantitatively to obtain some insights. The results indicate that, during the pandemic, the students adapted their senior project studies to the related restrictions by changing certain aspects related to the project, improving their teamwork, and increasing the level of communication. However, they also reported certain problems related to their overall psychology as well as social interactions. In light of the pandemic effect on the software industry towards remote working environments, further suggestions are provided to eliminate the drawbacks of remote working reported by the students and to equip them with the necessary skills. The resulting recommendations could be used by other higher-education institutions and be further adjusted for application in other disciplines.

Keywords: ICT senior/graduation project course; COVID-19 pandemic; virtual meetings; hybrid curriculum

1. Introduction

Senior projects are compulsory courses, where engineering students collaborates on assigned or self-chosen projects to reflect what they have learned during their undergraduate education program. As these projects require a high level of collaboration among the team members as well as between the team and the supervisor, they were specially impacted by the emergence of the COVID-19 pandemic. For example, in their study, the authors investigated the impact of the COVID-19 pandemic on the completion of digital design undergraduate students' capstone projects [1]. By the end of their comparative study based on quantitative analysis and qualitative interpretation, they concluded that the pandemic negatively influenced the students' performance and work quality. In another study, in order to enhance senior engineering students' skills, competencies, project quality, observability by external evaluators, and their employability under both in-person and virtual setups, an assessment center approach is proposed and implemented [2]. During the pandemic, several adaptation requirements emerged related to senior project courses, including asynchronous execution of theoretical classes converted to online group meetings, use of open-access online simulators, schedule extensions, and syllabus changes [3]. An important conclusion drawn by that study is based on its students' expectation questionnaire, which provided recommendations to keep the course in remote format or to merge it with a face-to-face teaching format [3]. Furthermore, according to the survey done by another study among the Fall 2020 senior design students to assess their engineering design self-efficacy and investigate how COVID-19 has shaped their capstone experience and the resulting self-confidence, she concluded that the students' engineering design self-efficacy was not correlated with the instruction format [4].

As collaboration and communication are critical for better developing such senior projects, the COVID-19 pandemic seriously affected these courses. Besides the communication problem, students had no access to their maker spaces to develop and test their products. As it is reported by earlier studies, finding new ways for the implementation of senior project courses is essential to help students [5–7]. Earlier studies have emphasized the importance of some standards and quality assurance processes for the graduates during the COVID-19 global pandemic [8]. In that concern, Goldberg has also suggested a hybrid model for the future implementations of the senior projects by applying virtual meetings and corresponding team management strategies [9]. Another study also suggests better preparing the software engineering students for their future careers by improving their skills in remote roles by helping them become familiar with some tools, such as Stack Exchange, GitLab, and GitHub [10].

In a three-part special issue of the International Journal of Engineering Education, several impacts

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of COVID-19 on engineering education and good practices made during the pandemic are shared with readers. For example, in [11], the results of a "student-centered" hybrid project-based learning teaching model practices made during the pandemic is introduced. In a research based on an applied questionnaire to a group of 1030 engineering faculty students to understand their perceptions during the pandemic period, the authors discuss both the advantage and disadvantages of students' online learning experiences [12]. Another research [13] in the same special issue proposes a collaborative autoethnographic approach that reflects the authors' teaching experience during pandemic and concludes with a table of best practices and recommendations. As it is pointed out in the future research sub-section of their article, an explanation of the phenomena based on a quantitative statistical method is required. Also, the students' insights should be included in any research that claims to be useful in future. Another requirement from which any future research benefits is longitudinal data collection across multiple semesters [13]. In our research, on the other hand, all these three requirements are satisfied, and we developed some useful post-pandemic recommendations for a hybrid curriculum of an undergraduate ICT senior project course.

The main motivation of this study is to describe the implementation of a senior projects course for IT students during the pandemic period, and to make recommendations for post-pandemic purposes. By following up the students throughout the course of three terms, the data about the implementation of the re-structured course was analyzed. Accordingly, the insights about the implementation of the re-structured course, as well as some suggestions about the future implementations of these courses, are provided. The results of this study aim to improve the implementation of the senior project courses and to better prepare the students according to the industrial requirements following the pandemic.

2. Literature Review

The recent pandemic has had a severe effect on higher-education programs. For instance, a significant increase in the grades obtained by students was reported [14]. Another study points out the necessity to develop new senior project team-working approaches and open environments for remote working, in which the emphasis shifts from instructor-driven learning to self-regulated team learning [15]. In the conclusion part of the research, the author asks whether the classical team-working experiences criteria are still valid in such socially shared learning environments [15]. We can still further expand this question by asking, "to what extent?".

Interestingly, an earlier study reports no significant difference between remote and traditional learning environments on a six-month-long project conducted by student teams under the guidance of an industry and a faculty mentor [16]. Research results also report the resilience of the software industry after the pandemic [17]. According to an earlier research, software developers' productivity improved after an adaptation period during the pandemic [18]. For instance, software companies have improved their agility [19]. Several studies have reported the successful management of software projects at companies during the pandemic [20]. Some freelancing platforms [5], or virtual versions of some tools, such as the virtual factory acceptance testing (FAT) tool [21], were also proposed for improving remote-team performance. Studies report that software engineers spend a similar amount of time working at home on certain activities to the amount they spend at the office, and that working remotely is not a big challenge for software developers [22]. Hence, the way the software industry has managed the pandemic problems could serve as essential guidelines for software education programs, especially senior projects [23].

3. Senior Project Course

This section describes in detail the senior project course and the changes applied to it in accordance to the COVID-19 pandemic restrictions.

3.1 Course Description

A senior project is required from all senior students (in the 7th or 8th terms) to partially fulfill the requirements for the B.Sc. degree in Computer/Information Systems and Software Engineering Departments of the university where the present research was carried out. The project lasts one term, and it is offered to irregular students as well. The weight of the senior project is four (4+0) credit hours for students and 4 hours/week for the supervisor and the project coordinator. The course is designed to develop and test a wide range of knowledge, abilities, and skills that may include problem-solving, information gathering and analysis, self-motivation, initiative, originality and creativity, technical knowledge and skills, software/hardware design skills, and communication skills.

The senior project course operates as follows: Before the term starts, the departmental boards assign a project coordinator and project supervisors according to the course load of the instructors and the number of students involved in the course. Then, the project coordinator invites the super-

visors to submit proposals in a standard format that is compatible with the projects' nature. The subject of the project should address a problem encountered daily or in business life, or it should be one that can prepare the students for post-graduate studies or the industry. If the students form a group of 3–4 people, they can collaborate with the supervisor they wish to work with. Afterwards, the project coordinator organizes the submitted projects, informs the eligible students on Moodle, collects their preferences, and assigns them to the projects in cooperation with other students and the relevant project supervisor. According to the guideline and weekly schedule announced, students begin working face-to-face with project supervisors for 1 hour per week.

Students submit their progress reports (called "Software Requirements Specifications" and "Design") during the term and before the final exams. These reports are formatted in accordance with the set rules. Report evaluation is made by the supervisor according to the specified grading system. Apart from the report evaluation, face-to-face code reviews are also carried out to measure the student's performance. Close to the completion of the project, the project coordinator invites the faculty staff to evaluate the projects during the "Project Presentation Day". On this occasion, which is a free event for anyone wishing to participate, students present their works informally. An examination panel for each project, composed of the coordinator and the supervisor, assesses the students and grades them.

3.2 Pandemic-Induced Modifications to the Course Execution

Before giving the details of the course-level modifications, we need to mention about the related university administration regulations and decisions made during the pandemic. First of all, instructors working in undergraduate programs were permitted and required to use the necessary materials and computers at home. All courses opened in the 2019–2020 Spring semester and not uploaded to Moodle yet have been uploaded by the Distance Education and Education Technologies Coordination Office. Research assistant support was given to academic staff who gave courses within the scope of distance education but declared that they would not be able to use Moodle. For each course given by the instructors, the necessary information and required materials about the course (including reference textbooks; PowerPoint presentations, reference source addresses, reference video addresses and also information about how to connect the student and weekly days and hours of the live connection) uploaded to Moodle. The Zoom software [24], which enables live online lectures, was provided by the university and necessary training on the use of the system was given to the academic and administrative staff.

With the normalization process, exams have started to be held face to face. As of the Fall and Spring Semesters of 2020–2021; some courses in undergraduate education are given entirely by remote format. Most of the other courses were carried out partly face-to-face and partly in online education format, and a few of them were carried out entirely face-to-face. There is no obligation to attend such courses. A significant part of the laboratories and practices were carried out face to face at the university. Midterm and final exams of all courses were conducted face to face.

As for most of the other courses, the pandemic affected the way of conducting senior project courses as well and required some course specific changes during and even later the period. This study compares and discusses three consecutive terms in this context from Spring 2019 to Spring 2020. The Spring 2019 semester – i.e., the first semester – started normally and as before; however, five weeks later, the onset of the pandemic was declared, forcing education to go online across the country and the three stated terms to be carried out as such with the help of the Zoom [24] platform and the related course materials shared with the students using the Moodle Learning Management System of the university. The Moodle system was already in place before the pandemic, but the Zoom platform, which has a wide range of functionalities such as screen sharing, chat window accessibility, virtual white boarding, group work and separate breakout rooms, was new.

Unlike the regular, non-pandemic period execution, all meetings, code review grading, after-poster presentations, and whole-project presentations were conducted online. Students submitted different parts of their project reports via the Moodle and the reports were evaluated by each project group supervisor. During code review, each student separately joined the meeting while the rest waited in the Zoom platform's waiting room until their turn came. In this way, the students who were in the waiting room could not observe their team members' verbal exchanges with the supervisor or interfere in any way, making it possible to achieve more objectivity in grading.

At the end of the term, each final project was presented by individual groups to two external academic staff for assessment. The presentation included a PowerPoint and a demonstration. The PowerPoint was presented by all group members in 15–20 minutes. Following the presentation, video demonstration of a maximum five minutes was

displayed by each team. Then, the question/answer part was held between the staff and each team for 5–10 minutes, amounting to a total of 30 minutes for each project group.

4. Materials and Methods

The present research was a longitudinal study conducted during the 2019-20-S (2019–2020 Spring), 2020-21-F (2020–2021 Fall), and 2020-21-S (2020–2021 Spring) terms in the IT (Computer Engineering, Software Engineering, and Information Systems Engineering) departments of the university. The data for this study was collected through a questionnaire (see Appendix), consisting of 38 items about the implementation of the course in each term. The survey also included some open-end questions to collect the general opinions of the participants about their course experiences. In order to support the results, the students were required to add a narrative subsection to their final project report in which they could freely discuss the impact(s) of the pandemic on themselves as a group, their project management, and the product they developed. Among a total of 51 projects (17 in Spring 2019–20, 9 in Fall 2020–21, and 25 in Spring 2020–21), 3 project groups for the Spring 2020–21 term did not submit their narrative subsections. In order to better understand the efficiency of the course, the data are considered both qualitatively and quantitatively.

Table 1. The distribution of students according to their gender

Gender	Frequency (F)	%
Male	63	63.6
Female	36	36.4
Total	99	100.0

Table 2. The distribution of students according to their term information

Term Status*	F	%
Yes	80	80.8
No, I have one more term to graduate.	16	16.2
No, I have more than one term to graduate.	3	3.0
Total	99	100.0

* (In response to the question: "Is this your last term to graduate?").

Table 3. The distribution of students according to their term information

Courses*	F	%
C $\leq$ 3	19	19.2
C = 4	8	8.1
C = 5	20	20.2
C = 6	19	19.2
C = 7	26	26.3
C $\geq$ 8	7	7.1
Total	99	100.0

* (In response to the question: "How many courses did you take this semester (C)?").

4.1 Participants

A total of 99 undergraduate IT students taking the Senior Project Course participated in the study. The sample size of all 3 terms was equalized as 33 for each term, and students were randomly selected. Detailed information about participants, including their gender and term information, is presented in Table 1 and Table 2.

The students' course loads are given in Table 3.

4.2 Data Collection

The data were collected through a questionnaire to explore the IT students' Graduation Project Course online learning acceptance, experience, and satisfaction during the COVID 19 pandemic. The survey was carried out on the last day of each term on a voluntary basis. The views of four experts were obtained to validate the content of the survey and the test assessment criteria. The reliability of the survey questions was computed as 0.803 and

Table 4. Classification of the Narratives

Analyzed Topic	Related Questionnaire Items
Descriptive	Q1, Q2
Distance Working	Q10, Q11, Q15, Q17, Q19, Q23, Q34
Drop or dramatic change in project	Q12, Q20
Faculty Interaction	Q5
Industry interaction	Q35, Q36
Meetings	Q6, Q18, Q9
Method	Q30
Project/Time Management /Planning/Costs	Q21
Psychology	Q29
Resource Usage	Q13, Q14, Q24, Q25
Self-improvement	Q22, Q26, Q27, Q28, Q31, Q32, Q33
User Requirements	Q16
Workload	Q3, Q4, Q7, Q8

assessed by applying the Cronbach Alpha test. A 5-point Likert-type scale was used as follows: 'strongly disagree', 'disagree', 'neither agree nor disagree (neutral)', 'agree', 'strongly agree', and 'I have no idea'. The normality test (Kolmogorov-Smirnov) was performed on the data set ($p < 0.05$). Since the normality assumptions were violated, a non-parametric Mann-Whitney U test was performed. The survey results were analyzed using SPSS (version 26; IBM Corporation, New York, USA) with a 95% confidence. The data collected as narratives from the open-ended questions were classified under 13 groups (Table 4).

5. Findings

The students' total online course hours was inquired in Q4, and the results appear in Table 5.

Table 5. The distribution of online courses

	F	%
$H \leq 15$	35	35.4
$15 < H \leq 20$	28	28.3
$20 < H \leq 25$	24	24.2
$25 < H \leq 30$	9	9.1
$H > 30$	3	3.0
Total	99	100.0

H: Total course hours taken online per week.

Accordingly, 52.5% of the students took between 15 to 25 hours of their courses online per week.

In Q11, the students were asked in what format they prefer to work in their future professional career in the Information Technology (IT) sector. The results are presented in Table 6, which shows that, in their future careers, the majority of the participants (65.7%) prefer to work in a face-to-face environment at the office, but with the support of online connectivity when necessary.

In this section, to determine the IT students' Senior Project Course online learning acceptance, experience, and satisfaction during the COVID-19 pandemic in online learning in the course of three consecutive terms, a non-parametric Kruskal-Wallis test was conducted. The distributions of scores were not similar among the groups as assessed by visually inspecting a boxplot. Table 7 presents the adjusted p-values, the results of post-hoc analysis, and the scores for each questionnaire item, which were statistically and significantly different among the different terms.

The Q5, Q6, Q7, Q8, and Q9 items were used in the analysis to better understand how many hours the students spent at weekly meetings with their supervisor, with their team members, for coding and development, for preparing project reports, and for pre-meeting preparations, respectively. It

Table 6. Choice between online and in-person environment in future professional career in IT

Preferred Project Execution Type	F	%
Face-to-face at the office, but with the support of online connectivity when necessary	65	65.7
Face-to-face at the office as in non-pandemic times	23	23.2
Only distant/online connectivity	9	9.1
I don't think that I will work in the IT sector.	2	2.0
Total	99	100.0

Table 7. The Kruskal Wallis Test results for three terms

Question	Mean Ranks			SD	X^2	P
	2019-20-S	2020-21-F	2020-21-S			
Q8 – On average, how many hours did you spend weekly to prepare the project reports for the course?	59.70	45.61	44.70	2	6.301	0.043
Q16 – Because of the pandemic, we had to drop/change some of the project requirements.	53.14	41.38	45.48	2	11.187	0.004
Q18 – During the pandemic, we were able to have more meetings online than face-to-face.	40.58	57.79	56.64	2	6.297	0.045
Q20 – During the pandemic period, we were able to continue the project without any additional problems.	40.08	54.50	55.42	2	6.264	0.044
Q21 – During the pandemic, time management was easier.	40.11	54.82	55.08	2	6.183	0.045
Q25 – During the pandemic, I used the resources and examples provided on the course Moodle site more effectively.	41.85	60.92	47.23	2	8.465	0.015
Q27 – During the pandemic, I was able to learn more from my friends.	41.71	59.97	48.32	2	7.331	0.026
Q32 – Doing frequent documentation during the pandemic contributed to my learning.	40.55	58.80	50.65	2	7.090	0.029

F: Fall, S: Spring

was found that the scores for Q8 were significantly different among the three terms, $\chi 2(2) = 6.301$, $p = 0.043$. The 2019-20-S has the highest mean rank (59.7) compared to the other terms.

The Q12–Q29, Q31–Q34, and Q36 items were asked to identify the problems of the students during the three terms in the pandemic period. Accordingly, the scores for Q16, Q18, Q20, Q21, Q25, Q27, and Q32 were significantly different among these terms. In Q16, $\chi 2(2) = 11{,}187$, $p = 0.004$. The 2019–20-S has the highest mean rank (63.14) compared to the other terms. In Q18, $\chi 2(2) = 6{,}297$, $p = 0.043$. The 2020-21-S has the highest mean rank (56.64). In Q20, $\chi 2(2) = 6{,}264$, $p = 0.044$. The 2020-21-S has the highest mean rank (55.42). In Q21, $\chi 2(2) = 6{,}183$, $p = 0.045$. The 2020-21-S has the highest mean rank (55.08). In Q25, $\chi 2(2) = 8{,}465$, $p = 0.015$. The 2020-21-F has the highest mean rank (60.92). In Q27, $\chi 2(2) = 7{,}331$, $p = 0.026$. The 2020-21-F has the highest mean rank (59.97). In Q32, $\chi 2(2) = 7{,}090$, $p = 0.029$. The 2020-21-F has the highest mean rank (58.80) when compared to the other terms.

6. Discussion

In this study, ICT students' perspectives about implementing the senior project course during the COVID-19 pandemic were inquired and analyzed in view of three consecutive terms. In general, the findings of this study can be summarized in the form of three headings as below along with the respective statements made by the students.

6.1 Conducting More Prolonged and Frequent Meetings

During the first term of the pandemic (2019-20-S), students had to spend more time on their weekly meetings compared to the other two terms in point (see Table 7, Q8), which involved less frequent meetings (see Table 7, Q18). The reason for this was the ease of arranging virtual meetings combined with the unexpected nature of the pandemic at its onset. For instance at the end of the first term, one group reported:

> "Apart from the negative effects of the pandemic period, it also benefited us. As the group members, the issues we had difficulties for meeting were generally transportation, intensity of our courses and creating common and free time. But since all our work is on the online platform, we did not have difficulty in creating common time and transportation. On the contrary, we had more time for our project since our free and common time was more than normal, which affected the period of our project very positively." (2019-20-S, Group #13)

Similarly, a group from the second term reported:

> "We encountered some positive and negative effects of having the SE494 [Software Engineering] course online during this period. One of the positive aspects is that we were able to hold meetings with our teammates for longer periods and more efficiently, regardless of time and place." (2020-21-F, Group #1)

Finally, a group from the third term stated:

> "Apart from this problem, when we evaluate the process, the pandemic has had a positive effect on our work. Our weekly meetings as group members have been much easier to arrange. Since we are in constant communication, our planned and spontaneous meetings online have provided us with convenience and time savings. Since we are all at home in this process, the time we can allocate to our project work has been more and more effective." (2020-21-S, Group #8)

Hence, with the effect of the pandemic, the students had to have virtual meetings with their group friends while writing their project reports. However, since they did not spend time in traffic and stayed away from social life, they were able to have both longer and more often virtual meetings, leading to more time at hand for project preparation

6.2 Appreciating Teamwork and Improving Its Efficiency

The results indicate that the students developed some skills to handle the additional problems brought on by the COVID-19 pandemic and its restrictions. They reported a higher confidence level concerning online working for the third term in question (2020-21-S) than in the previous two (see Table 7, Q20). Additionally, during the second term (2020-21-F), they reported a higher learning level from their friends than in the other terms (see Table 7, Q27). In that concern, their narrative descriptions also support these results. For instance, related to the second term one group from reports the following:

> "Due to lockdown and remote education, whole process of the graduation project had to be conducted on online platforms. This situation did not affect us negatively. Because we could meet with our teammates online at any time we wanted. We think that being online as a team is more beneficial for time saving and division of labor. This enabled us to develop our project more effectively." (2020-21-F, Group #5)

Similarly, related to the first term, another group claims:

> "On the other hand, this experience taught us how to manage and deal with remote jobs and projects that required to be dealt by separate teams and institutes. This experience also helps with understanding how important is task sharing, and managing those tasks and how an individual should deal with given tasks that bounds to another person that works in remote location. In short, it gives us another level of new communication and management skills in a way. We have finalized our project in given time window.

> Although it is predictable, it would bring different outcome if there was not an epidemic, yet it is not clear if that difference of outcome would be negative or positive at all." (2019-20-S, Group #15)

Finally, a group from the last term reported that:

> "During the pandemic process, the online course has had some positive and negative aspects. The positive aspects are that we spend more time in general and the availability of our groupmates increases. With the increase in availability, we had the opportunity to hold more meetings and we had a full team effort. We have gained a more active working environment by exchanging more ideas." (2020-21-S, Group #10)

From these findings, it can be seen that, especially during the pandemic, one can expect a high positive correlation between learning from friends and the students' teamwork efficiency. This is mainly due to the increased availability and accessibility of teammates provided via easily-organized virtual meetings. In this concern, earlier research also reports some benefits of virtual meetings such as teammates do not spend extra time for travel, being close to their family members and home environment, as this platform is un-formal platform, they have a chance to better get to know their teammates, they have a higher level of interactions in this informal platform and extra time for chatting away, getting mentorship and developmental feedback outside of content interactions [25]. Hence, these results encourage the educational community to implement virtual team meetings for several different educational setting. For instance, massive open online course (MOOC) platforms are created to provide quality education alternatives for everyone [26–28]. However, research results in those platforms report that, even there is a very high interest in those courses with very large number of registrations, students' engagement and their certification ratios are very low [26]. Implementation of such virtual meetings can be a model for improving the learners' interactions in the MOOCs and an alternative for creating project-based learning opportunities for the MOOCs as well, where earlier research also reports several benefits of project-based learning and team formation in MOOCs [29].

It should be stated that having fewer challenges with respect to the projects does not imply that the projects continued without a hitch, and that the existence of any additional problems could be expected to be mainly due to the negative effects of the pandemic and the related restrictions at their early stage. These negative effects can be assumed to have been adjusted to by the students in the course of time. Paired with virtual meetings and fewer project-related problems, this adjustment by the students might have contributed to this new approach to conducting ICT senior project courses.

6.3 Negative Effects of Virtual Meetings

There is also some evidence related to the negative effects of virtual meetings. The results indicate that students improved their time management skills as indicated extensively in the opinions collected in the third term (2020-21-S) compared to the others (see Table 7, Q21). The students also reported using the course Moodle site more efficiently during the pandemic. Such Moodle use reported at a higher level for the second term (2020-21-F) compared to the others (see Table 7, Q25). Despite such evidence showing that students improved their skills in time management and course website usage, they also made some reference to some negative effects of the virtual meetings.

For instance, a group from the second term states:

> "With the course being online, using Moodle active in this process was a good way for us by looking at the previous reports. In the weekly zoom meetings, our teacher taught us the way we should follow and what we should do. We were dividing the work by discussing our group work over zoom, but we could not find solutions to our problems quickly because we could not come side by side [together]. Although this result seems negative, this system actually taught us the importance of working and communicating with people we do not know professionally in our future business life, because jobs are not by a single person, would be executed with [in professional life, tasks are carried out by more than one individual]." (2020-21-F, Group #9)

Similarly, another group from the third term reported:

> "During this study, which was carried out in an extraordinary time such as the pandemic, we, as the study development team, were affected by many negative aspects. As these negative aspects, we can say that technological disruptions, decrease in interaction with the trainers and teammates of this study, decrease in motivation, deterioration of mental health by getting away from social life, and most importantly, the difficulty of being unable to control the project. If this study had not been carried out during the pandemic period, much more successful results could have been obtained. On the positive side, it saved us time in our project during this process. In short, the coronavirus has had both positive and negative effects, but for us, the negative aspects outweighed." (2020-21-S, Group #16)

Finally, another group in the same term adds:

> "There are not many negative aspects of conducting the course online. However, continuous meetings and tasks lead people to reluctance and distraction after a certain period of time. There were times when we got bored as a group because we were always interested in the same things. But we overcame it by hard work." (2020-21-S, Group #10)

A point is that, even though much time was saved via online meetings, the handling of the projects

might have been impeded by the students' low motivation and mental health deterioration due to lack of social life. As the narratives stated earlier point out, an important reason behind the students' reluctance, distraction, and boredom was endless meetings and increased tasks. However, they claim that they overcame such overload by working harder. One reason for the students' such negative behaviors could be the fatigue effect of the virtual meetings. Results of an earlier experimental study report that the use of cameras in virtual meetings creates a fatigue effect which creates problems in terms of employee voice and engagement in the meeting [30].

When analyzing the significant differences among the three terms, it can be seen that during the first term (2019-20-S) where students and the instructors were first faced with the pandemic, students reported more problems with time management, using the course resources on the Moodle, collaborating with and learning from their friends, and benefiting from frequent project documentation. The results show that, most probably during the second (2020-21-F) and third terms (2020-21-S), they developed some strategies related to these issues to improve the projects. These results indicate an adaptation by the students to the unexpected pandemic circumstances.

Overall, these results points to adjustments made in light of remote working. Despite its disadvantages, remote working offers certain benefits considering commuting to work, independence, and health-related issues. Hence, to better prepare the future engineers for such flexible work environments and provide some skills to handle such unexpected situations, the pandemic has several lessons for us. It was observed that the changes in the structure of the senior project course helped students to adjust the new settings. Accordingly, based on these results, and also as suggested by earlier studies [31], a hybrid model can be used for the implementation of senior project courses.

Such a hybrid curriculum approach may be a model for the higher education community from different perspectives. Creation of such hybrid curriculum for addressing different educational problems could be possible with synchronous and asynchronous implementation options in different educational settings [32]. Besides, studies report several benefits for creating hybrid problem-based learning courses promoting interactions and exchange among students and teachers [13]. On the other hand, earlier research also report that the distance/online education needs to be a part of the higher education programs [14], and there is an increased trend on mobile learning platforms [33]. These trends show the necessity of appropriate integration models for adapting these technologies into the current classical face-to-face education environments. For this end, this current study provides several insights for creating a hybrid curriculum of undergraduate ICT senior project courses. In the next section, some curriculum recommendations are given.

7. Curriculum Recommendations

Whereas in the span of three terms, the senior project course was conducted online successfully, both the students and supervisors were content with the end results. The course was held online out of necessity; however, the online mode is also preferable for certain other aspects. For example, time became more easily manageable by students, who learned to develop their own strategies accordingly and used the Moodle-based materials more effectively. Before the pandemic, students had to find time slots that were convenient for all of them to work on their projects. Such meetings used to be limited, and there was no such habit of meeting after school. However, during the pandemic, they became used to having online meetings whenever and wherever they wished; in this way, producing project outputs with high quality. More meetings and more frequent interaction between the students and supervisors, at the same time, eliminated any likely problems associated with such work as well. Therefore, it can be concluded that, after the pandemic, the implementation of the following terms can be hybrid for a more practical course configuration. Adaptation to new strategies and approaches for engineering students during their senior project was easier and more encouraging for them, and it can also be an opportunity to share their experience with their employers and colleagues in future. According to our findings, it is inevitable that holding courses in the future will change and be shaped by making use of technological advantages to meet the educational needs without sacrificing quality and standards. This will not only improve the online education skills of the educators [14], but also improve several skills of the students which will help to prepare them for the working sector expectations in a better way. Some evidence requiring such changes has been reported by the earlier studies as well [3]. During the pandemic, the software industry workers also had to adapt themselves to remote working conditions. In that concern, they report some benefits, such as being close to family members; however, others have problems sharing the working space with family members due to interruptions [10]. The researchers report that the post-pandemic environment will change the working

traditions [10]. As also reported by another study, a shift will take place toward more flexible work arrangements in the software industry, referred to as the ''remote-first and hybrid teams'' trend, which they expect to become increasingly common [34].

In parallel with the results of this current study, to better prepare our graduates for the software industry, a hybrid curriculum for the senior project courses is a necessity. For instance, in such a hybrid curriculum, the interactions between team members and the instructor can be conducted as three weekly meetings remotely and one weekly meeting in a month as face-to-face to bring together all the projects' materials and physical outputs. Additionally, virtual meetings can often be organized among the team members to synchronize their work better and manage their projects. These face-to-face meetings can also be conducted for socializing among the team members and for improving their communication. Similarly, during the course activities, such as coding, bug-fixing, meetings, communication, code-review, documentation, can be combined and learning can be mixed through some hybrid approaches. As also indicated by our results, both e-learning environments and face-to-face classroom activities have several pros and cons. The results of this research study encourages researchers to better understand the advantages and problems of both environments and develop appropriate strategies for an efficient hybrid curriculum.

8. Conclusion

In this study, qualitative and quantitative data collected from the ICT senior project students were analyzed to better understand the impact of the pandemic on these courses. First, it is found that the virtual meetings had several benefits for the project teams thanks to no place and time restrictions; they were able to conduct longer and more frequent meetings. This, in turn, improved their way of handling the problems of the project, thereby facilitating teamwork and communication. However, some disadvantages such as psychological concerns and absence of socializing environments were also reported. These findings related to the effect of the pandemic on the software industry guided us to support a hybrid curriculum for the ICT senior project to prepare them for their project and course performances as well as the industry requirements in future.

Such a hybrid approach can also be implemented in other suitable courses in the engineering curriculum at different levels. This may improve peer interactions, help the students become better prepared for the courses together with their peers, and turn into an approach to implement some instructional techniques, such as flipped classrooms. We believe that the COVID-19 pandemic helped us to better understand the e-learning tools and platforms and how to get benefits of them in our classroom learning environments as well as the necessity of hybrid curriculum.

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Appendix

A questionnaire on distant execution of it students' graduation projects during COVID-19 pandemic period (20.06.2020)

Please, answer the following questions while considering your experience in distant execution of the CMPE/SE/ISE 494 Graduation Projects courses in the COVID-19 Pandemic Period.

Question 1: Your gender.

Female ☐ Male ☐

Question 2: Is this your last term to graduate?

Yes
No, I have one more term to graduate.
No, I have more than one term to graduate

Question 3: How many courses did you take this semester (C)?

$C \leq 3$ ☐ $C = 6$ ☐
$C = 4$ ☐ $C = 7$ ☐
$C = 5$ ☐ $C \geq 8$ ☐

Question 4: What is the total online course hours per week that you have taken this semester (H)?

$H \leq 15$ ☐
$15 < H \leq 20$ ☐
$20 < H \leq 25$ ☐
$25 < H \leq 30$ ☐
$H > 30$ ☐

Question 5: On the average, how many hours did you spend in weekly meetings with your supervisor for the course?

1–3 hours
4–7 hours
8–12 hours
13–20 hour
More than 20 hours

Question 6: On the average, how many hours did you spend in weekly meetings with team members for the course?

1–3 hours
4–7 hours
8–12 hours
13–20 hour
More than 20 hours

Question 7: On the average, how many hours did you spend in weekly for project coding and development for the course?

1–3 hours

4–7 hours
8–12 hours
13–20 hour
More than 20 hours

Question 8: On average, how many hours did you spend weekly to prepare the project reports for the course?

1–3 hours
4–7 hours
8–12 hours
13–20 hour
More than 20 hours

Question 9: On the average, how many hours did you spend in weekly to be prepared for the meetings of the course?

1–3 hours
4–7 hours
8–12 hours
13–20 hour
More than 20 hours

Question 10: Which one of the following graduation project execution type you would have preferred?

Only online distance interaction
Face-to-face but supported with online distance interaction
Only face-to-face as in normal time

Question 11: In what format do you prefer to work in your future professional career in Information Technology (IT) sector?

Only distant/online connectivity
Face-to-face at the office, but with the support of online connectivity when necessary
Face-to-face at the office as in non-pandemic times
I don't think that I will work in the IT sector

Answer the questions 12–17 below by considering the problems that you are faced with due the pandemic period.

Question 12: Because of the pandemic, we had to change our project topic.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 13: Because of the pandemic, we could not reach the hardware in the Laboratory required for our project.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 14: Because of the pandemic, we could not bring together different hardware parts of the project.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 15: Because of the pandemic, we had some integration problems as we could not be able to conduct face-to-face meetings.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 16: Because of the pandemic, we had to drop/change some of the project requirements.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 17: Because of the pandemic, we could not integrate different software parts of the project.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 18: During the pandemic, we were able to have more meetings online than face-to-face.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 19: During the pandemic period, we improved our level of collaboration in project development.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 20: During the pandemic period, we were able to continue the project without any additional problems.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 21: During the pandemic, time management was easier.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 22: We were more productive than the period before the pandemic.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 23: If there was no pandemic, our project would not be as successful as the current one.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 24: During the pandemic period, I used existing internet resources more efficiently.

Strongly disagree
Disagree
Neither agree nor disagree

Agree
Strongly Agree
I have no idea

Question 25: During the pandemic, I used the resources and examples provided on the course Moodle site more effectively.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 26: During pandemic period, I improved my self-learning process.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 27: During the pandemic, I was able to learn more from my friends.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 28: During pandemic period, I was personally more productive than before-pandemic period.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 29: The anxiety involving the COVID-19 outbreak affected my concentration and performance on online execution of graduation projects course, negatively.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 30: Have you had trouble completing any of the project steps due to the pandemic period? You can choose more than one option.

Literature Review ☐
Software Requirements Specification – SRS ☐
Design ☐
Implementation/Coding ☐
Testing ☐
Deployment ☐
No, we did not have any difficulty ☐

Question 31: Having frequent meetings during pandemic period contributed to my learning process.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 32: Doing frequent documentation during the pandemic contributed to my learning.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 33: Doing frequent coding during pandemic period contributed to my learning process.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 34: In general, were you satisfied with the graduation project course execution in the pandemic process?

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 35: In this semester, if you are working as a part-time that is related to your education, did this experience contribute to your graduation project?

Yes ☐
No ☐
Partly ☐

Question 36: It is appropriate for my project products to be evaluated distantly and interactively by non-university individuals like other university academics and/or IT professionals.

Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
I have no idea

Question 37: Discuss the positive impact(s) of the Pandemic period on your graduation project execution.

Question 38: Discuss the negative impact(s) of the Pandemic period on your graduation project execution.

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