The Importance of the Campus - A Study on the Effects of the COVID-19 Pandemic in a CS2 Course

Madeleine Lorås, Børge Haugset, Hallvard Trætteberg
Department of Computer Science
Norwegian University of Science and Technology
Trondheim, Norway
madeleine.loras@ntnu.no

***Abstract*—The educational context for students and educators across the world changed when the COVID-19 pandemic forced most educational institutions to shut down all on-campus activities in the spring of 2020. In this paper, we explore how the study behaviors of first-year computing students in a large scale CS2 course were affected by the rapid change from campus-based to online learning. This research aims to evaluate the effect of moving to an online-only mode of studying and learning, and consequently gaining insight into the role of the physical campus in computing education. A mixed-method research approach was taken to reach these goals by combining interaction tracking data with weekly student reports and interviews. Results indicate that campus-based activities provide essential scaffolding for students' study behaviors, specifically time management and organization. Additionally, the physical study environment provided an informal space for social and academic interactions not found in the online sphere. Furthermore, when moving to the online study environment, students struggled with adapting their study behaviors, spending less time on organized activities and not changing their independent habits. Lastly, the online environment seemed to create considerable differences between those who mastered studying and those who did not, generating a larger ability gap than on campus. In the paper, we provide further descriptions of these findings and some recommendations for computing educators facing similar challenges.**

***Index Terms*—Computer Science Education, Computing Education, Higher Education, Study Behavior, CS2, Educational Design, Online Learning, Remote Learning, Study Environments**

I. Introduction

What happens to the students when all physical interaction suddenly disappears overnight? This is indeed a strange question to ask, or would have been at the beginning of 2020. However, we currently live in a world where almost all higher education institutions have had to close down all face-to-face teaching at some point. When the COVID-19 pandemic took hold of the world in the first part of 2020, institutions across the globe had to go from campus-based education to online education. Online education has been around for a while; however, for many educators, students, and administrators, this was a whole new situation.

When the pandemic hit Norway, all campus-based education was shut down on March 12th. Universities and schools across the country were given the order to transfer into the online setting and complete the semester digitally as best we could. In this paper, we will take a close look at how a classic campus-based CS2 programming course dealt with this sudden change. The focus of this study is on the student perspective and how they experienced the change from campus-based to online learning.

Soon after it became clear that we had to go online for the foreseeable future, the authors of this paper began collecting data and identifying ways to learn from this situation. The goal of the current study was twofold. On the one side, we were interested in evaluating the effect of going online on the student experience since we are looking at a minimum of one more year with very limited use of the campus. On the other hand, this unfortunate situation provides an interesting natural experiment on what happens without a campus. In other words, what is the importance of the physical learning environment for the students learning experience? This last part can enlighten our understanding of what aspects of the traditional campus-based design are most important to the students learning, what they can 'live without,' and where we can adjust and improve. In this paper, we aim to answer the following research questions:

- RQ1: How did the students interact with the changes made to the educational design due to COVID-19?
- RQ2: How did the students' study behavior change when going from a campus-based to an online study environment?

The paper is structured as follows. Section II describes the course design before and after the pandemic forced an online transformation. Section III describes the methodology, data collection, and data sources, while Section IV presents analysis and results. Lastly, in Sections V and VI, we discuss the results, as well as reflect on lessons learned. This contribution provides an illustration of how a course was fully digitized within a short time frame and explores the effects of these changes on the student experience which can inform our educational designs coming back to the campus.

A. Study Behavior of Computing Students

This study focuses on the student experience in the light of study behavior development through the abrupt transition from campus-based to online learning due to the pandemic. Therefore, it is necessary to clarify some concepts and theories regarding study behavior in computing education before moving on to describing the study and educational context

further. Study behavior is a complex concept and has seen many definitions and terms over the years, both in general education research and in computing education. In this study, we understand study behavior in the broadest sense, relating to any actions students take when preparing for, or taking part in, study-based activities, based on the definition in Tressel, Lajoie and Duffy's review in 2019 [1]. This definition includes the students' interaction with organized learning activities (i.e., lectures, labs, assignments) and how they do their independent studies (i.e., time management, revision, strategies, attitudes). The current study is based on previous work by the authors on computing students' behaviors, specifically, and the interaction with educational design [2]. In this framework, students' study behaviors are divided into the following five dimensions, which will be used for the analysis:

- **Organization**: How students interact with organized learning activities and manage their independent study
- **Independent study**: What tactics the student employs outside of organized learning activities
- **Planning and priorities**: Management of the course load
- **Time management**: When the students study: what days and what times of the day
- **The study environment**: Where the students study

Previous research on the study behavior of computing students' relevant to the current study has suggested that meaningful learning happens during students' independent study [3], [4], and that organized activities in the classroom does not seem to be the primary driver of learning [5]. In general, study behaviors have been found to affect academic performance and learning significantly [6]. How students do their assignments and to what extent they learn from such assignments has also been investigated, finding that assignments help students structure their studies and ensures progression [3], [7]. On the other hand, when discussing the independent study, procrastination is an issue several studies have investigated, finding that it indeed is an issue for computing students and very often leads to decreased academic performance [8], [9]. Most educators and researchers within computing education agree that in order to master any computing concept, students must learn by doing [10], [11]. Moreover, in the online environment investigated in the current study, the students are required to manage this learning and doing alone. Therefore, the current study of students' study behaviors in an introductory computing course comparing on-campus and online behaviors is important to the community.

II. The CS2 Course

The research presented in this paper is based in an undergraduate object-oriented programming (OOP) course at a large university in Norway. The course yields 7.5 ECTS and goes over 14 weeks with a final four-hour exam, in the end, accounting for the whole grade. For the first nine weeks, the course was campus-based, as described in Section II-A, while for the last five weeks, the course was online (Section II-B). It is relevant to mention that two-thirds of the way through the semester, there was a two-week break for Easter, with no scheduled teaching and learning activities. The course has one professor, three head teaching assistants (graduate students), and 40 teaching assistants (undergraduate students). The programming language used is Java, and the course covers topics such as classes and objects, encapsulation, object structures, exception handling, and inheritance. Students generally take this course in their second semester and are required to have completed an introduction to information technology course, which includes programming in Python. The course is mandatory for all the various computer science and computer engineering programs and serves as an elective course for many other engineering programs.

A. The Campus Environment

In the following sections, we will describe the CS2 course design in the campus-based environment before the pandemic caused an online transformation. This course design described below has been in place for eight years, with revisions to the assignments being made regularly. The student feedback is generally positive; however, the workload has been criticized somewhat. On the other hand, students report that the amount of practice and experience with programming in the course is very useful.

1) Tools and Communication: The course uses the learning management system Blackboard (BB) to host all communication and information. Teachers use BB for announcements, sharing slides and resources, and organizing assignments. In addition to BB, the course used Piazza to host discussions and answer questions. The Piazza platform allowed students, teaching assistants, and faculty to interact with each other and has options for anonymity.

2) Lectures and Labs: During the semester, there are four hours of topic lectures and two hours of exercise lectures a week. The topic lectures are given by faculty and cover theoretical perspectives as well as practical examples. The exercise lectures are given by the head teaching assistants and focus on the assignment given that week. The exercise lectures introduce the assignments, give tips on relevant techniques for the upcoming assignments, and go through solutions for previous assignments.

In addition to lectures, there are open labs where students can get help. These labs are staffed with teaching assistants and are open from 0800-1800 every weekday. Students who need help or have questions can drop by at any time; however, each student is placed in a group with a designated teaching assistant (TA). With this designated TA, they will be prioritized in the event of queues. Although this system seems complicated, it has proved to be an effective system for maximizing the chance that students will get help when they need it and utilizing all TAs. The course also has a course wiki page with content about OOP and Java.

3) Assignments and Support: There were ten mandatory assignments in total. They did not count towards the final grade; however, each assignment was awarded points between 50-100, and to qualify for the exam, the student had to reach a total of 750 points. The assignments were based on

the curriculum for the current week and the week before. Automatic tests are integrated with the assignments so that both students and teaching assistants (TAs) can quickly check the code. To pass the tests, students have to code correctly for all edge cases, as well as name their methods according to the task description. All students must hand in the assignment individually; however, collaboration is allowed as long as it is labeled.

The assignments are delivered online but have to be demonstrated in-person to their designated TA within a week after the deadline. TAs are generally older students who have completed the course, hired by the department to give feedback, help students with their assignments, and assign points to each assignment. Each TA is responsible for 20 students and is available in the open labs for at least six hours every week.

4) Exam and Assessment: The course grade is based on a final exam. The exam lasts four hours and is given in a secure online assessment platform under supervision. This system allows students to write their code with syntax highlighting but does not provide any other integrated development environment (IDE) features, including compiling. Over the last five years, the average grade for the exam has been a C, and the failure rate has been between 16-23%. If students fail the exam, they have the opportunity to retake the exam at the end of the summer, before the next semester begins.

B. The Online Environment

When the government ordered a total shutdown of all physical interaction on campus, the course had to go digital and create an online environment for remote learning. Table I outlines the changes made to the educational design, which will be further described in the following subsections.

1) Tools and Communications: In addition to the already existing BB and Piazza sites, the course administrators (lecturers and head TAs) also opened a Microsoft Teams site for the course. The goal of this Teams site was to ease the interaction between lecturers, TAs, and students. It was an important consideration to only use tools that were accessible, secure, and in line with privacy rules (GDPR). Since the university uses Microsoft products, Teams was available for all staff and students, and the required security and privacy requirements had already been vetted and cleared.

On March 13th (the day after the announcement), all students were invited to join the new course Teams site. The Teams site had six channels: General (announcements and general remarks), Lectures (links to video lectures), Lectures – Q&A (questions about the lectures), Exercise lectures (links to video lectures), Exercise lectures – Q&A (questions about the lectures) and Support (see Section II-B3). The reason for having separate channels for lectures and Q&A was so the lecture links did not drown in questions and would remain easy to find for the students.

For the remaining five weeks of the semester, all essential information would be given on BB, while the Teams site was used as an additional recourse. Video lecture links were posted on both sites. The Piazza forums remained in use.

2) Lectures and Labs: The lecturer and head TAs started producing video versions of their lectures soon after the initial setup. They decided to go for an asynchronous design, where the video lectures would be posted as soon as they were done, and students were free to watch them in their own time. The lectures were grouped by topic, which in turn, related to an assignment. The videos were posted on the university platform for video sharing, which during the time period changed from Mediasite to Panapto.

At this point, a second lecturer, who had taught the course for several years previously, was recruited to help with the course. The two lecturers would set up the lecture as a conversation, where one would do the coding while sharing his screen. While coding, one instructor would tell the other what he was doing and why, while the other would comment and ask questions. This setup aimed to simulate a more interactive setting, and both lecturers remarked how they enjoyed doing the videos together in this way, as opposed to just filming themselves alone. The head TAs chose the same setup for their exercise lectures.

When it comes to the open lab set up on campus, this was directly transferred to Teams. The TAs would work the same hours in the digital lab as they had in the physical lab, answer questions, support students, and follow up with their designated students.

3) Assignments and Support: The remaining four assignments went as planned, although Assignment 6, which had a deadline on March 13th, was given a one-week extension. The students were still required to hand in their code on BB and demonstrate their work to their TA via video chat in Teams. Each TA was given the task to create a private channel in Teams for his/her students to arrange these demonstrations.

In addition, the TAs were required to be available the digital lab during their normal work hours. This digital lab was accessed through the "Support" channel in Teams. A student in need of support would post "I need help" in the channel, and the next available TA would call them up via video chat. In order to keep track of who was getting help, the TA would like the post to indicate it was taken care of.

4) Exam and Assessment: Pretty soon after the online transformation, both students, educators, and administrators started thinking about the exams. The university soon announced that all traditional exams were canceled and needed to be either oral (via video call) or a home exam. In addition, all course teachers could, if they wanted, change the grading system to pass/fail. This course decided to keep the grading scheme and do a four-hour home exam. This decision was discussed extensively internally and with the students, causing quite a debate. Many considered the pass/fail option as more gentle on the students considering the situation they were in, as well as easier to administer, control, and grade fairly. On the other side, many viewed the grades as important motivators for the students to learn and were concerned that students who had put in the effort so far would not be rewarded the good grade they deserved.

TABLE I: Overview of course design in the campus based (pre pandemic) and online environment (post pandemic).

	Design parameter	The campus environment	The online environment
Course structure	Open or closed enrollment	Open for all students at university	Open for all students at university
	Number of students	841	841
	Class schedule	4 hours lecturing a week	Asynchronous video lectures of remaining topics
		2 hours exercise lecturing a week	Asynchronous video lectures of remaining topics
		Open labs on campus all week (08-18)	Open labs in Teams at the same times
	Mandatory attendance	No	No
Learning activities	Individual or group-based activities	Individual, but collaboration is allowed	Individual, but collaboration is allowed
	Number of assignments and/or projects	Weekly/biweekly mandatory assignments	Weekly/biweekly mandatory assignments
	Learning management system etc.	Blackboard, Piazza	Blackboard, Piazza, Microsoft Teams
	Available resources	TAs in open labs	TAs available on Teams
Educators	Number of lecturers	1	2
	Lecturer-student contact	Mainly through lectures	Mainly on Piazza
	Number of TAs	2 Head TAs	2 Head TAs
		1 TA per 20 students	1 TA per 20 students
Assessment	Type of assessment and exams	End of semester school exam accounts for the whole grade	End of semester home exam accounts for the whole grade

III. Methodology

The rapid change from campus-based to online education provides a natural, although, unplanned experiment. In this study, a class of 841 CS2 students spent the first eight weeks of the semester following a traditional campus-based course. In week 9, the course was changed to be all online. As this was not planned, we do not have all the data points one would expect from an experimental study; however, we do have some data from before and after the intervention, as well as post-intervention data [12], [13]. In general, this study's research design can be viewed as a mixed-method quasi-experimental empirical investigation of a course [14].

A. Data Collection

The data collected in this study comes from three data sources: learning reports, tracking of interaction, and interviews. The learning reports were a mandatory part of each assignment where students were required to self-assess through reporting when, where, and how they had worked on the assignment. These learning reports provide insight into the students' study behaviors, in this case, both before and after the transition to online learning. In addition to the pedagogical benefits of self-reflection, these reports are a part of ongoing research on study behavior; hence, the students have provided consent to use their data for research purposes.

The second data point is the tracking of interaction with the various digital platforms. We were able to track the students' engagement in Piazza both before and after the online transformation. Additionally, we tracked the students' interaction in Teams and views of the video lectures. As this data was not connected to the individual student, but a count of the frequency of use, the need for informed consent is void. BB was not included in the tracking data because the students did not interact with BB outside of submitting assignments. Since the assignments were mandatory, there was no change to BB's interaction patterns throughout the semester.

Lastly, the researchers were able to conduct interviews with seven students after the transformation. Four of the interviews were done via written chat in Teams, while three were done over video chat. The students could choose which medium they preferred. The audio from the video chats was transcribed and added to the written logs. All interviews were directed by an interview guide, created by the authors based on findings from a preliminary survey among students and educators in the first weeks after the intervention [15]. The text from the interviews was merged and coded into the categories used in this analysis.

B. Participants and Considerations

The students participating in this study were all enrolled in a computing study program: computing engineering, informatics, technology management, engineering and ICT, communication technology, or teaching and computing. The gender distribution in the course is approximately 70/30 male to female. The students' ages and nationalities were homogeneous, with an average age of 20 and no international students. Among the 841 enrolled students, 452 consented to use their learning report data for research purposes (54%). We did not gather gender data for the learning reports; however, there is no reason to believe the gender distribution should be any different from the course. Four of the students participating in the interviews were female, and three were male.

All participants were granted informed consent for the collection of learning report data and the use of interview transcriptions for research purposes. The Norwegian Centre for Research Data has approved this. It is important to state that the first author of this paper was not involved in the planning or implementation of the course but was granted access to all the tools and platforms. This independent person handled the data collection and analysis, and the course teachers (remaining authors) were only involved in the discussion of results.

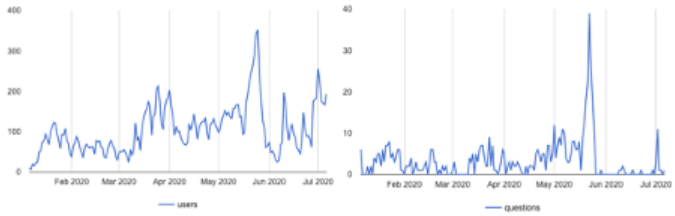
IV. Analysis and results

In order to answer the first question of how students interacted with the changes to the educational design, we present the tracking and interview data. For the second question, regarding the change in the students' behavior in the online learning environment, we additionally present the data from the learning reports.

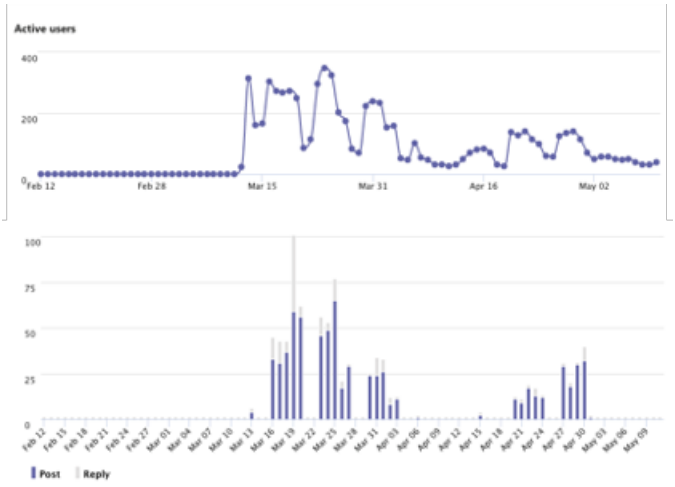
A. Student Interaction

Using the same division as in the previous sections, we will, in the following, present the relevant results for each aspect of the course in addition to describing the method of data extraction and analysis.

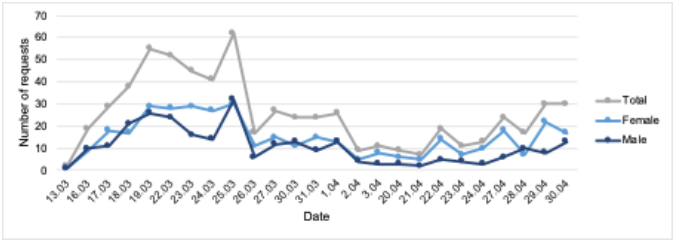
1) Tools and Communications: From the Piazza platform, we were able to extract data on the number of engaged users per day, as well as the number of questions posted. These data can be viewed in Fig. 1a, from the beginning of the semester (late January) until the results of the exam were published in July. It is evident that after March 12th, there was a slight increase in the number of engaged users; however, the number of posts does not seem to see the same steady surge. There is, however, a large peak right around the exam (May 25th). From examining the posts' content, it is clear that there were many questions posted in the days before the exam, as well as several comments on the exam after the fact. In total, 794 students enrolled, and 226 students made a sum of 2402 contributions.



(a) Piazza usage



(b) Teams usage



(c) Teams support interaction

Fig. 1: Study behaviors over the first semester.

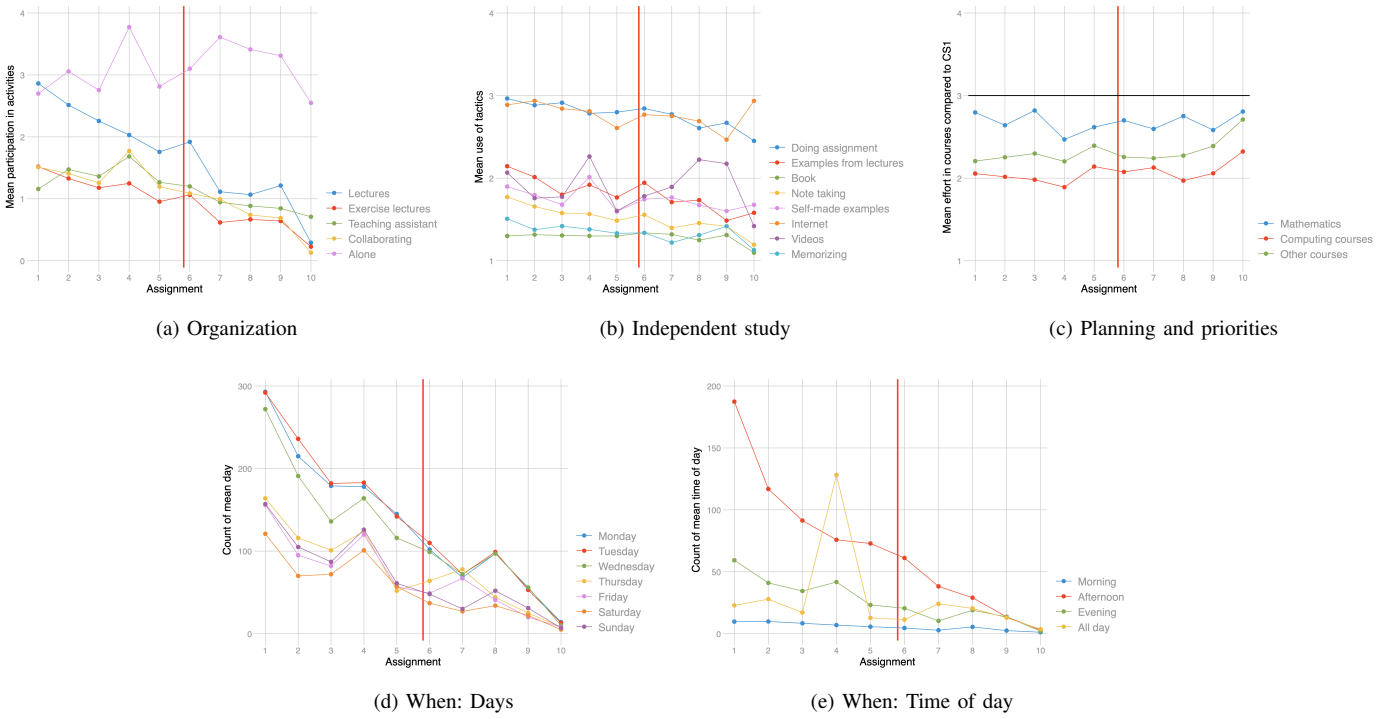
We have similar data for the Teams platform; however, only for the period after March 12th. Fig. 1b depicts the number of engaged users and posts from February to the beginning of May. In contrast to Piazza, the Teams' engagement shut down after lectures and assignments had ended, indicating that no exam preparation or commentary happened on Teams. Similar to the activity on Piazza, the number of active users and posts grew in the immediate aftermath, decreased towards the Easter break, and then grew slightly again towards the end of the lectures (end of April). In total, 931 students and TAs engaged, and 694 contributions were made. Unfortunately, Teams does not allow us to differentiate between students, TAs, and teachers, so we have no way of systematically identifying who made these posts.

Data from the interviews revealed that the students, in general, were content with the tools and communication used in the online setting. Interestingly, many of the students said they did not participate in the discussions or ask many questions but learned a lot from reading through what others wrote. Several students commented on the fact that the number of tools used in total for all their courses was overwhelming at times; however, they were very satisfied with the CS2 course.

2) Lectures and resources: The researcher collected viewing data from all the posted videos manually after the exam. Since there were several platforms in use, this was the only way to collect a full overview of engagement with the videos outside of the students' self-reported data. The most viewed lecture video was the first one made (718 views), while the average was 350. It is evident that the first video of each topic gained the most views, decreasing views until the next topic. The most viewed exercise lecture had 436 views and was the first of the course summary videos, while the average was 287. There seems to be a similar trend with exercise videos, with decreasing views throughout the series, but not as significant a difference as regular lecture videos.

In the interviews, students reported different experiences. On the one hand, some students seemed very positive to the freedom of asynchronous video lectures. They said they enjoyed being able to regulate their learning pace by choosing when to watch them, adjust speed, and re-watch sections they did not understand at first. On the other hand, some students reported that using video lectures took a lot more time, was harder to follow, and less motivating than in-person lectures. Generally, the latter group of students reported that studying from home was less effective than on-campus studying.

3) Assignments and support: The use of support through the open labs was tracked by manually counting each post in the Support channel in Teams. The results of this exercise can be found in Fig. 1c. Each post was categorized by gender. As seen in the figure, the number of help-seeking posts peaks close to the assignment deadlines, with the most significant peaks coinciding with the deadlines for Assignment 7 (March 20th) and 8 (March 25th). At this point, the students who had finished all eight assignments most likely had reached the threshold of 750 points, which probably explains the decrease of posts for the remainder of the semester.



(a) Organization

(b) Independent study

(c) Planning and priorities

(d) When: Days

(e) When: Time of day

Fig. 2: Study behaviors by assignments.

We were interested in observing any gender differences in help-seeking behaviors, and there seemed to be a higher number of female students using the online open labs than males. Since the gender distribution of the class population is unbalanced, the percentage of females using the online support channel is significantly higher than for males. However, we cannot be sure of this conclusion since we were not able to count unique posts. Additionally, we do not know how this compares to the on-campus open labs.

When it comes to the interview results, the experience with the assignments and support structures showed similar tendencies to the experience with lectures. Some students were very favorable to the change; some even said the new system worked better than the old one, while other students said the exact opposite. The latter found it more complicated to find help and found calling TAs over video intimidating.

4) Exam and assessment: In the period after assignments were done and before the exam, students seemed to use Piazza rather than Teams to ask questions and discuss. During the interviews, students commented on the fact that a home exam was going to be new to them and expressed some nervousness about that. Besides, the fact that the exam would be graded came up repeatedly. Several other courses chose to change the assessment to pass/fail, while this CS2 course kept the graded regime. In the interviews, the students consistently said that this course would be prioritized since it was graded and that they were motivated to study for the exam.

Immediately after the exam, discussions about how the exam started and continued far into the summer. In general, the discussion was on the level of difficulty on the exam. Many students expressed that the exam was too hard; however, the grade distribution was in line with previous years. The average grade was C, failure rate 21%, and the grade distribution as a whole was very similar to previous years.

B. Change in Study Behavior

Thus far, we have looked at engagement and interaction with the organized learning and teaching activities; however, we were also interested in exploring students' independent studying and priorities. Following the framework presented in the introduction, we will examine the students' study behavior across four dimensions: Independent study, Organization, Planning and Priorities, and Time Management (TM). Data were extracted from the students' learning reports, giving us one datapoint per student for each assignment (N=2084).

Fig. 2 depicts the results from the students' learning reports across these dimensions by assignment. For all ten assignments, the mean of each behavioral construct for the student population as a whole was calculated and plotted. Based on this plot, we see some interesting tendencies. There seems to be little change between the campus and the online environment for the organization and independent study dimensions. Planning and priorities seem to be the same throughout the semester; however, time management sees a steady decline throughout the semester.

The tentative findings from these graphs were further explored statistically by looking at each dimension's individual behavioral constructs. However, this proved to be a challenge

as the research design, and data collection were not planned for this purpose. Therefore, it did not entirely fit any of the traditional methods of analysis. After some time was spent exploring variable transformations and various non-parametric tests, the authors landed on dividing the dataset into two random groups in order to create independent subsets [13]. The students were randomly placed into one of two groups, with their accompanying learning report data. Group one was analysed using data from assignment 1-5 only (campus environment, n=742), and group two used data from assignment 6-10 (online environment, n=300), thus creating two independent groups. The *n* here refers to the number of valid learning reports used in the analysis. Then, a Wilcoxon-Mann-Whitney test was performed in Stata [16] to examine the difference in study behaviors on campus and online, that is, before and after the pandemic hit. The dependent variables were the different study behavior constructs illustrated in Fig. 2 and were investigated individually against the independent variable. The independent variable was dichotomous, indicating if the assignment was campus-based (0) or online (1). As seen in Table II, these tests provide a slightly different picture of the situation for students. For organization, the tests indicate that there was a difference in study behavior on campus and online, similar to the plots. However, for independent study, the tests found a significant change in all behaviors except for the use of the book, internet and videos, which is not evident in the plots. When it comes to planning and priorities, both the tests and plot indicate no significant differences, while the time management dimension, on the other hand, seems to differ in both.

TABLE II: Summary of differences between the campus and online environment on Wilcoxon-Mann-Whitney rank sum test

	Campus	**Online**	
Organization	Rank sum	Rank sum	z-value
Lectures	427266.5	116136.5	9.39***
Exercise lectures	417672	125731	7.47***
TAs	410832	132571	5.78***
Collaboration	412549.5	130853.5	6.12***
Alone	373270	170133	-3.18**
Independent Study			
Doing assignment	397035	146368	2.55*
Book	386949.5	156453.5	-0.001
Note taking	396441	146962	2.65***
Self made examples	391671	151732	1.22
Lecture examples	400379	143024	3.32***
Internet	394448.5	148954.5	1.78
Videos	384844	158559	-0.52
Memorizing	391904.5	151498.5	1.59
Diagrams	421227.5	122175.5	8.60***
Planning and Priorities			
Math	386888	156515	-0.02
Other computing courses	382223	161180	-1.10
Other	386167	157236	-0.18
TM: Days			
Monday	498253	45150	25.57***
Tuesday	498253	45150	25.57***
Wednesday	498253	45150	25.57***
Thursday	482803	60600	22.02***
Friday	490013	53390	23.67***
Saturday	498253	45150	25.57***
Sunday	498253	45150	25.57***
TM: Time of day			
Morning	396912.5	146490.5	2.68**
Afternoon	419575.5	123827.5	7.55***
Evening	399054.5	144348.5	3.06**
All day	388558.5	154844.5	0.441
N	742	300	

$*p < 0.05, **p < 0.01, ***p < 0.001$

In the interviews, there were some consistent tendencies when it comes to how their study behavior changed. Firstly, the students who described their routines in the campus-based environment as very structured, all had set up similar structures at home, however, the students who were less structured before reported struggling in the online environment. The latter group referenced challenges getting up in the morning, watching all the lectures, and getting started on assignments. They said they missed the lectures and interactions on campus and commented on how that used to help them progress in their learning. Secondly, many students reported that their study hours were changed. Some students said they kept regular working hours, while others reported studying later in the day, and on weekends (something they did not do before). Lastly, many students commented on the social aspects of not being on campus, and several mentioned that they were lonely and felt very isolated. Although many students said they had started informal study groups with friends meeting online, the students consistently commented on the fact that not meeting their peers was challenging. In general, the students who reported negative experiences seemed to be the students who lacked structure in their study behavior, and who might have struggled in the campus environment as well.

V. Discussion and related work

This study set out to investigate the differences in computing students' study behavior in the campus-based and online environment, and their interaction with the changes in educational design caused by the COVID-19 pandemic. Firstly, there is a plethora of research on campus, online and blended learning and study environments, both in general education research and the computing education field. With the growth in usage of MOOCs/SPOCs, blended and flipped instructional designs, gamification and online assessment systems, there are many avenues to explore in the literature. To clarify terminology, one could argue that the course investigated in this paper was never fully on-campus, as the students could 'get away' with only meeting their designated TA on campus once a week. All the assignments and submissions were accessible via online platforms, and the lectures and labs were not mandatory to attend. Nevertheless, the authors would argue that the course was not a blended course because the educational design was not intended for the online environment. The lectures were not recorded, and all support was offered only on campus. If the students chose not to utilize these on-campus resources, there was no online alternative. In other words, it was expected of the students to spend time on campus and participate in the educational activities.

In the following discussion, we will explore the results of the current study in light of the research questions and related research. Additionally, it has been pointed out by researchers in the field that we must be careful not to directly compare "emergency remote teaching" to online learning [17]. In the following discussion we aim to explore the online *environment* created by emergency remote teaching and how the students' behaviors developed in this new context.

A. Student Interaction

When it comes to the use of tools and communication channels in the online environment, it is interesting to compare the students' engagement in Piazza and Teams. Piazza received a higher engagement overall, which is not surprising, considering it was used throughout the semester. However, it is striking how Piazza seemed to be the preferred platform for communication when there were no organized activities in place. When the TAs and educators were active on Teams, the students engaged in the tool; however, they preferred Piazza when there were no scheduled activities. One reason for this might be that Piazza was the more familiar platform considering it had been in use in the campus-based environment as well. On the other hand, previous research on computing students' self-regulation strategies proposes that targeted scaffolding will help students adapt their learning [18], [19]. In this case, we can view the scheduled activities within the online environments as a way of scaffolding students' study behavior, which explains the interaction patterns. Additionally, a contributing factor might be that Piazza allows anonymous interactions. The researcher noticed that nearly all students used the option to post anonymously on Piazza, which is not an option in Teams. Lastly, the findings from the interviews regarding the number of tools might also explain this trend; perhaps the students simply preferred to use just one platform.

The current findings on online lecture views are aligned with previous research in the field [20], [21]. Students will watch the early videos but gradually watch less. Previous studies on student viewing patterns have found that the viewing of complete videos decreases as the complexity of the content increases [20], [22] as well as high correlations to assignment timelines [21]. When it comes to the student experience, the interview findings were similar to the general feedback on face-to-face lectures. There is a large discrepancy in how individual students perceive the effectiveness of lectures. Therefore, it is important to consider that with the social component of meeting friends in lectures gone, many students might opt out of watching lectures online [23], [24].

When considering the assignments and support-seeking interaction, the results indicate that the online system worked well. The fact that the number of support requests in the open lab was low relative to the total number of students in the course is somewhat discouraging; however, the students seemed very content with the system. The interview findings suggest that the students also used their designated TA in private channels, and were satisfied with the support they got. On the other hand, previous research on help-seeking behavior and meta-cognition in online and blended environments has found that the students struggle to identify their need for support in time [19]. Additionally, the gender distribution of these posts is interesting, suggesting that female students ask for help more often than males, and it would be interesting to explore this further in relation to similar studies [25].

In general, these results suggest that there is a larger difference between students' study behaviors in the online environment than the campus-based. The interviews indicated similar trends in large individual differences when it comes to lectures, resources and support in the online environment. Based on the collective results, it seems like the difference between the students who mastered the online study environment and those who did not was larger than in the campus environment. In other words, students who were successful and experienced mastery with their study behavior on campus were able to transfer to the online environment without issues. In contrast, the students who struggled on campus struggled even more online. To the best of our knowledge, this has not been identified in any previous research. Furthermore, it is difficult to say whether this is a computing specific finding or general for all students. As second-semester computing students, these students should be accustomed to independently developing their programming skills by transferring the knowledge from lectures and assignments to skills and competencies in CS2.

B. Change in Study Behavior

The change of study behaviors in the campus and online study environment was explored further through plotting means over time and statistically testing the differences. Looking at the graphs as a whole, there are some interesting findings to point out. Firstly, some assignments differ from the rest. Assignment 4 seemed to provoke an increase in most behaviors and in time spent. This discrepancy can be explained by the nature of assignment 4, which was a project-based assignment where the students themselves defined the project over two weeks (the teachers defined the remaining assignments). Furthermore, assignment 8 and 9 see similar tendencies, although not as large. This might be due to the fact that most students would be finishing their required 750 points with a full score on assignment 8/9. Lastly, assignment 10 has largely the opposite results, except for independent study tactics, which was most likely due to the students changing strategies because they are preparing for the exam, and not actually the finishing of assignment 10. Nevertheless, there seems to be a connection between student behavior and assignments also in the online environment [3], [7].

The way the students organized their time seemed to change somewhat in the two different study environments: students spent the same time alone; however, the time spent in lectures, with TAs and collaborating with other students, decreased. When it comes to independent study, students, to a large extent, utilized similar tactics on campus and online, with the exception of videos that seemed to increase slightly. Comparing the effort in CS2 to other courses, there seemed to be no change in the campus-based and online environment.

From the plotting of when students studied, it is evident that the total time spent studying likely decreased since the use of all days and times of day seemed to go down. In general, this is true for the whole semester, and the pandemic might not have had an impact here.

Under organization, it can be observed that with the exception of time spent alone, there seemed to be a statistically significant difference between all the behaviors in the campus-based environment and online. Similarly, for independent study, only reading the textbook, using the internet and videos stayed the same after the online transformation. When it comes to planning and priorities, no statistical difference was found, which is in line with the plots in Fig. 2. Lastly, the analysis of when students studied indicated that both the days and time of day students studied changed.

All of the significant tests indicated that students spent less time or participated less in the online environment activities, something that is clear from the plotted means as well. These somewhat conflicting results can be interpreted in three ways; the students spent less time studying and participated less 1) because of the pandemic, 2) because it was closer to the end of the semester, or 3) a combination of the two. In previous studies comparing campus, online and blended environments, it has been found that time management and effort regulation positively influence grades [26]. Furthermore, study strategies focusing on effectively scheduling, planning, and self-managing study time, while correctly allocating resources and effort despite potential distractions, is more challenging for online learners and more important in a highly autonomous study environment. Seen in connection to the finding on larger differences between students who master the online environment and those who do not, these are the behaviors that seem to be the cause of this difference.

One last finding that is important to discuss comes mainly from the student interviews, and it is difficult to quantify in any statistical way, is the importance of the informal study environment provided by the campus. The social interactions between students, educators and TAs in lectures and labs, happening in breaks, queues, and between various organized activities seemed to be missing in the online environment. Online, students need to know each other's full names in order to contact each other, and it requires scheduling to be working on the same courses at the same time [27], [28]. Connecting with peers has been found to be a sizable challenge for students in an online environment, especially for informal learning interactions [26]. Although informal academic socializing did seem to happen in ad hoc groups, these are invisible to the whole student group, and we are certain many students were left out. The campus provides an open environment, where names and schedules are irrelevant when students naturally meet. Going into a third semester of uncertainty about the availability of a campus, creating an informal academic environment is the hardest challenge we aim to solve.

C. Limitations

In retrospect, there are many things we would do differently, although, considering the sometimes chaotic circumstances, we believe this research is of value. This study has a somewhat unorthodox research design, where the data collection was guided by the access to data, rather than the research questions, which provides some limitations to the research. Mainly, the lack of longitudinal data for all data sources and the fact that we did not have the opportunity to test learning or performance in any meaningful way.

In addition, the transformation for students from a campus-based to an online environment was not the only change for the students during this time period. The country was in full lock-down for several weeks, and the students lost not only access to the campus but also all other infrastructure such as gyms, cafes and public spaces. Many students also moved from their student housing to their parents' house, where their whole family was also most likely working from home.

VI. Implications and Key Takeaways

This research aimed to both expand our understanding of the role of the campus-based study environment for computing students, and provide some lessons learned for other educators in the future. It is clear that the campus plays an important role in many students' study day. Campus-based activities provide scaffolding for students' study behaviors, specifically time management and organization, as well as providing an informal space for social and academic interactions. When moving to an online study environment, students seem to struggle with adapting their study behaviors. They spend less time on organized activities and do not change their independent study habits. Lastly, there seem to be larger differences between those who master studying and those who do not in the online environment, creating a greater ability gap among the student group. Although we did not investigate the effect of this gap on performance, there is reason to believe that this will lead to a significant knowledge and skill gap.

In addition to these important lessons learned for the online environment, this research has also given us some valuable insight on the importance of the campus. Specifically, aspects of campus-based education created indirectly by the educational design. It is clear that valuable learning happens between lectures and labs, in various nooks and crannies of the campus. Learning to learn is an essential competency for future computing engineers and professionals, and one of the important findings of this study is that many students struggle with this skill. It is important now to look back at the traditional educational design and reflect on what we can improve. When hopefully returning to the campus based environment soon, we should use this opportunity to reflect on that practices we take with us from this experience with emergency remote learning. Based on the results in the current study the following questions can be used to kick off this discussion:

- When returning to the campus, how can we maximize the potential of the informal learning spaces? It seems

like the campus is essential to the students. At the same time, we know many students spend a lot of time alone at home during a traditional semester. What can we do to engage these students on campus?
- Is the fact that lecture attendance is low in many courses an even greater problem than we thought? Should we be more worried about the students who do not actively use the campus based environment?
- Is the scaffolding provided by the set time-tables and educational structure doing the students a disservice? What can we do to improve students' ability to study and learn independently?
- How do we use online tools in a way that creates interaction, accessibility and engagement? Do we need to consider teaching the skills to use these tools effectively? Furthermore, how can we support students in creating effective help-seeking behaviors?

Researchers and educators spend significant time and resources on designing, implementing and evaluating different learning activities and innovative approaches, however the current study suggest that there are important things happening outside our designs. Viewing these results though the lens of learning theories, the prevalence of constructivism in computing education can further guide this work [29]. Assuming that learning is achieved through students constructing knowledge, these results indicate that many of these constructive interactions happen outside the educational design constructs. Designing computing courses and programs that facilitates the creation of informal learning spaces and supports the development of effective study behaviors will be essential for educators in the future, regardless of the study environment. Students will need the knowledge and skills to be able to construct knowledge independently, both on campus and online, in order to be prepared for the unpredictable future.

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