Student Perspectives on On-site versus Online Teaching throughout the Covid-19 Pandemic

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Abstract—**We present a long-term study of how university students experienced teaching/learning activities throughout the Covid-19 pandemic in Denmark[1]. We collected data through questionnaires from N=365 students enrolled in the "Introduction to Database Systems" course during four consecutive semesters (Spring 2020 to Fall 2021). The two years span the entire period of the pandemic's interruption of normal on-site teaching, until restrictions were completely lifted in Denmark. The study investigates student preferences for online versus on-site teaching, and identifies the advantages of both, as well as changes in preferences throughout the pandemic. Quantitatively, the results demonstrate a preference for on-site over online teaching which was more pronounced for exercise classes than for lectures. Qualitatively, the study identifies several advantages of both online and on-site teaching; including a more engaging *learning environment* and better teacher-student *interaction* for on-site lectures, and *flexibility* and *self-paced learning* for online teaching. The primary changes identified were *an increased sense of being able to focus online* and a *decrease in ease of asking questions online* towards the later stages of the pandemic. Finally, we highlight the opportunity for universities to provide *hybrid* models of teaching, in order to care for diverse student preferences and needs.**

Index Terms—**Covid19 pandemic, online teaching and learning, hybrid teaching, student preferences**

I. Introduction

On March 13, 2020, Denmark entered a national lockdown in response to the global Covid-19 (SARS-CoV-2) pandemic. By national decree, all teaching had to be offered online at all universities in the country. By April 2020, around half the world's population (almost four billion people from more than 90 countries) had been asked to stay home to avoid the spread of the disease [1].

In the following semesters, as the situation remained critical, Danish universities adopted different strategies in adherence to ever changing government guidelines. Hybrid solutions were implemented to guarantee social distancing, and recorded lectures were provided to allow asynchronous attendance. Despite the tragic circumstances, this provided a unique opportunity to study students' perceptions of on-site versus online teaching and learning.

In this paper, we present data collected during four semesters (Spring 2020 to Fall 2021) of both BSc and MSc students attending the course "Introduction to Database Systems" at the IT University of Copenhagen in Denmark. The research analyzes the students' perceptions of teaching and exercises in different formats. The context of this research is a leading university specialized in computing education, where online teaching was rapidly implemented in March 2020, with the institutional and technical support of a dedicated administrative department.

By exploring the student perceptions of the transformations that have occurred throughout the pandemic's disruption of teaching, the study offers a reflection about the digital future of computing education in the post-pandemic university [2].

II. Related Work

A vast body of literature on emergency remote teaching in higher education has been produced since the beginning of the pandemic [3]–[5]. Among the challenges faced by universities worldwide, some studies have found evidence of structural problems, related to teachers' readiness for online teaching [6], [7], institutional organization and agility [8], [9], as well as network instability and internet access [10].

Several studies have also highlighted drawbacks related more specifically to the quality of online teaching, such as lack of teacher–student interaction [11] and difficulties in adapting face-to-face lectures to the virtual format [12]. It has been stressed that academics have struggled with the limited

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[†]Research conducted while the first author was at the IT University of Copenhagen, Denmark.

[1]In Denmark, the first Covid-19 restrictions were put in place during the spring of 2020, and all restrictions were completely lifted during the spring of 2022. At the time of writing this article, the first (and hopefully last!) wave of the Covid-19 pandemic was therefore fully contained within this period.

timescale of the transition to online teaching, which was often in conjunction with their personal obligations and resulted in concerns about well being [13] and lack of motivation [11]. Social distancing has also negatively affected students' achievements by causing uncertainty, anxiety, physical discomfort, and stress [14], [15].

On the other hand, research shows that online teaching can offer new opportunities when the quality of lectures is assured [16], the institutions show technical preparedness [17] and students are able to self-regulate their learning process [18]. The self-paced mode of learning is in fact a strength of the online format [19], and it proves stronger when combined with responsive teaching [10] and constant feedback [20]–[22].

Rapanta et al. [23] studied online/on-site teaching in the Covid-19 situation with teacher interviews and qualitative data analysis. They concluded that online teaching has proven to be a space for trying new things, especially with the support of materials. However, on-site teaching is perceived as a much richer experience by students, who emphasized that the teacher's personality emerges.

Potra et al. [24] qualitatively surveyed 149 first-year students in Romania about their experience of online, on-site and hybrid teaching, focusing on challenges and opportunities for an educational model. The students expressed four main challenges related to online teaching: information overload, limited interaction, lack of focus, and teacher-related hindrances (e.g., lack of technical skills, and improper adaptation of face-to-face teaching to the online format).

Yagi et al. [25] surveyed a sample of 114 medical students undergoing clinical clerkship during the Covid-19 pandemic. A multiple regression analysis showed that *accessibility* and *comprehensibility* were determining factors for satisfaction and future preferences.

Collectively, existing research shows that on-site and online teaching in higher education are different in terms of teaching styles, use of materials, and mediation. Generally, results point to a preference for on-site lectures for most students; however, few studies examine whether these preferences *changed* during the course of the pandemic and few studies investigated *hybrid* teaching formats. The study presented in this article sheds light on students' preferences along two years of restrictions due to the Covid-19 pandemic, for lectures as well as exercises classes, and for classes taught fully online, fully offline, and in hybrid formats.

III. BACKGROUND

We now provide relevant background on the Covid-19 pandemic and the educational context in which our study is situated.

A. Covid-19 Pandemic

Figure 1 provides an overview of the pandemic in Denmark since the beginning of the pandemic in terms of the number of hospitalizations[2] related to Covid-19 [26]. Three distinct

spikes are discernible, coinciding with seasonal fluctuations; in particular, with winter in the northern hemisphere. The figure also reports on the lockdown stages during this period of time in response to the spread and control of the disease. For comparison, the population of Denmark is 5.8 million, so the maximum of 1,762 hospitalizations correspond to about 0.03‰ of the population. Towards the far right of Figure 1 (labelled *post-pandemic*), we see that the pandemic is receding in Denmark, due to the fact that 90% of the eligible population has been vaccinated and about half of the population has already contracted Covid-19 [26] (not accounting for *re-*infections).

Importantly, our study investigates student perspectives on on-site versus online teaching during exactly the four semesters that were impacted by Covid-19 restrictions, interrupting the normal unrestricted on-site teaching.

B. Educational Context

This study was conducted in Denmark which is a democratic society with a well-organized tuition-free public state-funded educational system. Universities are characterized as egalitarian, non-authoritarian, and informal where students enjoy a large freedom under responsibility. Students are entitled their own opinions without fear of repercussions; incl. whether education ought to be conducted on-site or online. Denmark is ranked at the top of the Digital Economy and Society Index (DESI) [27] which is a (proxy) indicator of the readiness to take education online. The study revolves around a 7.5 ECTS[3] course "Introduction to Database Systems" which runs twice a year at the IT University of Copenhagen. During the spring semester, the course is offered in the second semester of the Master (MSc) of Software Design. The students are a mix of Danish and international students who have a Bachelor degree of some kind (most often in something unrelated to computing) of which around 20% are women. During the fall semester, the course is part of the third semester of the Bachelor of Software Development and the Bachelor of Data Science with around 40% women, in total. The Software Development students are mainly Danish. Data science students are a mixture of Danish and international students.

IV. METHODOLOGY

We use questionnaires with both quantitative and qualitative questions in order to address our research objective. Our objective is expressed in three research questions and results are gathered with both statistical and thematic analysis.

A. Objective

This research is guided by the following three research questions:

> **RQ1 (preferences):** To what extent do university students *prefer* on-site to online teaching/learning activities (lectures and exercise classes)?

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[2] We use the number of Covid-19 hospitalizations as a proxy for the spread of the disease (which is correlated with the number of infections and deaths).

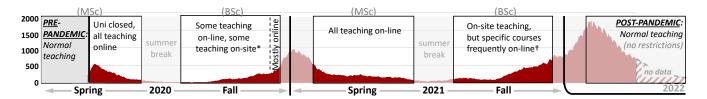[3] 1 year is 60 ECTS (European Credit Transfer and Accumulation System).

Fig. 1: Contextual overview of the pandemic in Denmark: Number of hospitalizations from the start of the pandemic in Denmark (March 11, 2020) to the latest available data point (April 29, 2022), annotated with the Covid lockdown stages during the four semesters (Spring 2020 to Fall 21). *On-site with minimum-distance requirements (at least one meter). †Online because of rising infection numbers along with a general fear of contracting Covid-19.

RQ2 (advantages): What do university students perceive as *advantages* of on-site and online teaching/learning activities (lectures and exercise classes), respectively?

RQ3 (changes): How has university student perceptions of on-site versus online teaching/learning activities (lectures and exercise classes) *changed* throughout the pandemic?

B. Study design

The course "Introduction to database systems" and extraordinary circumstances offered a unique opportunity for gathering a wide range of perspectives on online and on-site teaching, as the students come from different semesters and different programs, yet have all been exposed to the same learning material and content at different times throughout the pandemic.

Teaching/learning activities are split into a traditional structure with theory-inclined teacher-centric *lectures* with demonstrations along with more practical, hands on, student-centric *exercise classes*. The formats of the four semesters were as follows:

- **Spring 2020:** Halfway through the semester (on March 11), lectures as well as exercise classes were moved from being entirely on-site to entirely online (cf. Figure 1). The students thus experienced both on-site and online, precisely 6 weeks for each format.
- **Fall 2020:** Lectures were entirely online, while students had to choose whether they wanted exercises on-site or online. In late November 2020, all exercise sessions were moved online, due to proliferation of the disease.
- **Spring 2021:** Both lectures and exercise classes were conducted exclusively online.
- **Fall 2021:** Both teaching and exercises were fully hybrid; each week, students were allowed to choose (without disclosing their choice to fellow students) whether they preferred on-site or online. Therefore, the students could experience both on-site and online.

The Spring versions of the course were offered to MSc Students whereas the Fall courses involved BSc students.

C. Questionnaire

As explained in the section above, students experienced different conditions during the four different semesters. This means that the questionnaire was altered slightly to match the different formats; for instance, we could only ask students if they preferred *hypothetical* on-site teaching when their lectures had, in fact, been held exclusively online. In terms of structure, the questionnaire was orthogonally divided into *lectures* and *exercises*. For each of these two kinds of teaching/learning activities, students were asked to quantitatively compare [hypothetical] on-site versus online teaching overall (using a 5-point Likert scale); and, to qualitatively argue (using open text fields) what worked better on-site, respectively, online.

Lectures:

- How do you compare the [hypothetical] **on-site versus online** experience during *lectures*? (5-point Likert scale)
- What, if anything, [would have] worked **better on-site** during *lectures*? (Open textual answer)
- What, if anything, worked **better online** during *lectures*? (Open textual answer)

Exercise Classes:

- How do you compare the [hypothetical] **on-site versus online** experience during *exercises*? (5-point Likert scale)
- What, if anything, [would have] worked **better on-site** during *exercises*? (Open textual answer)
- What, if anything, worked **better online** during *exercises*? (Open textual answer)

For the students who had a choice between online or on-site (Fall 2020 and Fall 2021), the questionnaire also asked which mode they had chosen (on-site or online) and what the reasons were for that choice. The survey was administered using Google Forms.

In total, $N = 365$ students (of 718) answered the questionnaire (which was offered optionally towards the end of the course), corresponding to an overall response rate of 51%. The response rate of around half of the students is fairly consistent over the four semesters: 46% (57/124) for Spring 2020, 55% (110/201) for Fall 2020, 56% (83/148) for Spring 2021, and 47% (115/245) for Fall 2021.

D. Data Analysis

For statistical analyses, we performed Kolmogorov-Smirnov tests of normality. These revealed non-normal distributions, and we therefore used Sign tests to compare preferences in lectures versus exercises (as each student provided a score for both), and Mann-Whitney U tests to compare changes
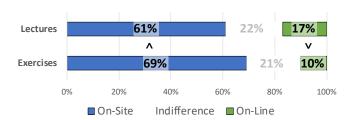
Fig. 2: Distribution of preference ratings for *on-site* (to the left, in blue) versus *online* (to the right, in green) teaching for both *lectures* (top) as well as *exercise classes* (bottom).

in preferences over time (as these compared different student populations). For all statistical analyses we adopted two-tailed tests and a confidence level of 5%, as is customary.

Qualitative data was analyzed using thematic analysis [28] in NVIVO. The method is directed at the formalization of the process of developing themes, given that a theme represents a patterned response in the data set [29]. Thematic analysis does not only rely on frequency counts of words or phrases, but rather their relations in forming meaningful concepts [30]. Thematic analysis was performed by one of the authors and focused on 'identifying and interpreting key, but not necessarily all, features of the data, guided by the research question' [31].

The topics that emerged from the data were divided in the following codes: teacher effort; flexibility; self-paced learning; focus; questions; learning environment; teacher-student interaction. The first three codes referred to online teaching. The last two referred to on-site teaching. Finally, two codes—focus and questions—were found in relation to both advantages of online and advantages of on-site teaching.

V. RESULTS

Our results are presented separately for the three research questions. For each, we offer relevant quotes from students along with observations.

A. Preferences for on-site versus online teaching? (RQ1)

Figure 2 shows the reported **preferences** for *on-site* (to the left, in blue) over *online* (to the right, in green) teaching, reported separately for *lectures* (top) and *exercises* (bottom). In general, students prefer *on-site* to online teaching and a sign test shows that this preference is significantly more pronounced for exercise classes than for lectures ($z = 5.31$, $p < .001^{***}$). In fact, while only one in *six* (17%) students prefer online *lectures*, a mere ten percent prefer online *exercise classes*. We observe:

> **OBSERVATION 1A:** Students appear to prefer *on-site* to *online* teaching/learning activities (lectures and exercise classes).

> **OBSERVATION 1B:** The preference for on-site teaching/learning activities is significantly more pronounced for exercise classes than for lectures.

Our findings are consistent with related work, e.g. [32]–[35].

B. Advantages of on-site versus online lectures? (RQ2)

Qualitative thematic data analysis suggests more advantages of on-site than online teaching in all four semesters. This section is structured by the themes of on-site and online teaching, and the codes identified by the thematic analysis are highlighted in **bold**.

1) Advantages of on-site teaching: The greatest advantage of on-site teaching is described as the power of the (physical) **learning environment**, which includes the social aspect of peer exchange and the engagement that students experience in a physical setting. In the qualitative analysis, the learning environment code appeared in 108 responses during the four semesters and increased in frequency (14, 19, 38, 37):

> *The sheer presence of other students. Being on-campus gives a sense of a "learning environment," being able to chat with other students in the breaks and discuss relevant topics superficially etc. That whole feeling of actually attending university is lacking online, and that seriously hampers my motivation and self-control for studying.* [MSc student - Spring 2020]

> *There is a more natural environment for discussing both content and logistics with your fellow students, since everyone is already there. To me a university course is much more than just a professor guiding you through knowledge, it is also the environment that the course provides. Taking a course on-site usually inspires and energizes me greatly every time i go to a lecture, this does not happen at all when online (actually quite the opposite).* [BSc student - Fall 2020]

> *I find it more difficult to learn and discover on my own. As a product of on-site lectures, students tend to discuss topics after lectures and share newly discovered articles, videos or other formats of information.* [MSc student - Spring 2021]

> *Being able to participate during the lectures. Being able to questions asked and being there physically to answer and "get a feel of the room" is very giving.* [BSc student - Fall 2021]

Another advantage of on-site teaching that has been widely mentioned by the respondents (56 answers) is **teacher-student interaction**, which was sometimes related to the support of the blackboard for exercises and explanations:

> *The face-to-face lectures made the teaching more clear, and much more understandable (it is hard to teach without, for example, a blackboard we can all look at!) and it was easier to ask questions face-to-face, and get good answers.* [MSc student - Spring 2020]

> *Live performance! Allowing the teacher to really interact with the crowd.* [BSc student - Fall 2020]

> *The whole teacher/student dynamics is better on-site; it's easier for the teacher to "feel" the room and*

easier for the student to be concentrated, focused and "present." [MSc student - Spring 2021]

You are sure to hear everything the lecturer says + it feels more normal in terms of just interacting with people. [BSc student - Fall 2021]

Among less frequently recurring advantages mentioned by the students, we coded 16 answers under the category **materials**. The respondents especially refer to illustration on the blackboard, which can be useful for some explanations.

I think it is harder to get clarified your questions online and understand the lecturer's teaching without being there physically. Especially, regarding the use of the blackboard to explain for instance regarding the more technical issues as how the database works. Everything was new to me and even though it was really hard to understand from the readings and lectures. [MSc student - Spring 2021]

Some concepts (Normalization with ABCD type of exercises) might be better to see live on a black board instead of on slides. [BSc student - Fall 2021]

We summarize the advantages of on-site teaching:

OBSERVATION 2A: According to students, the main advantages of on-site teaching are the physical *learning environment* and *teacher-student interaction*.

2) Advantages of online teaching: In relation to the format, students have reported that online teaching allows for **flexible and self-paced learning**. *Flexibility* is especially related to *synchronous* online classes, which were described as convenient to attend in the event of illness or distance from the university; while *self-paced* learning refers especially to *asynchronous* teaching. This aspect is appreciated by many students: 157 have mentioned the advantage of accessing recorded lectures for a better understanding and/or preparation for the exam. Sometimes, however, they have stressed it as the *only* advantage of online teaching:

Comfort and convenience, means I won't miss any lectures regardless of my, too often, poor mental/physical health. [MSc student - Spring 2020]

The only positive thing about online lectures is that I can watch the lecture from my couch and do not have to commute since I live far away. [BSc student - Fall 2020]

The recording of lectures and possibility to watch them later is *excellent*. I sincerely hope this will become the standard from now on, even when lectures are held physically. [MSc student - Spring 2021]

The best part about online lecture is not the lecture it-self, but the recording afterwards. The recordings are really useful when reading up to the exam or if you simply just didn't manage to write all down in your notes, then you can watch it later to get your notes completed. [BSc student - Fall 2021]
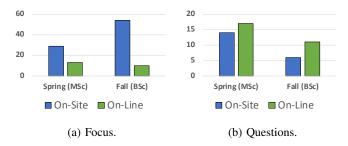

(a) Focus.   (b) Questions.

Fig. 3: Number of students stating that they find it easier to either *focus*, respectively, *ask questions* on-site versus online.

Of the N=365 of total responses to the survey, 37 students acknowledge the **teacher's effort** to prepare and carry out high quality online classes despite pandemic circumstances:

His great mood and humor have made me love this course the most! Also, I very much appreciate the time he's taken to post extra videos going through hand-ins and extra topics. [MSc student - Spring 2020]

The teacher has been very good at making it interactive and asking questions and communicating has been excellent. [BSc student - Fall 2020]

I think the online teaching worked surprisingly well, there was time to ask questions, there was good visualization - all in all, a very well-structured course! [MSc student - Spring 2021]

He is by far the best professor, when it comes to include online participation, the use of cameras and overview of the chat, means it possible to feel included almost as much as on-site. [BSc student - Fall 2021]

Another advantage frequently mentioned (16 answers) is that students can get a better **view of the screen** under the online educational setting:

Easier to see what happens on the board than with 200 people attending. Good seats are fought upon. [BSc student - Fall 2020]

If one uses visualization tools, that can be easier on-line. [MSc student - Spring 2021]

Finally, five answers revolve around taking advantage of the private **home environment** during teaching: having something to eat without disturbing the rest of the class (3 answers); and, the convenience of moving in the home space while listening to the lecture (2 answers).

We summarize the advantages of online teaching (abstracting away the efforts of a particular teacher):

OBSERVATION 2B: According to students, the main advantages of online teaching are the *flexible and self-paced learning* and a *closer view of contents* shared on the screen.

3) Diversity of preferences: Finally, the data revealed two aspects that are mentioned in relation to both on-site and online

teaching, with different explanations. These are: (i) **focus**; and (ii) **questions**. In the first category, **focus**, 84 respondents focus better while attending on-site classes, while 23 respondents find it easier to focus online (see Figure 3a). For on-site teaching, students point to the learning environment:

> *Less distractions and a crowd of students all paying attention, boosts information retention.* [BSc student - Fall 2020]

Online teaching is highlighted for the convenience of the physical home office environment:

> *Better study environment for concentrating, better home office setup (easier to take notes etc).* [MSc student - Spring 2021]

In the category coded as **questions**, 28 students prefer the online setting for asking questions, while 20 students find it easier to ask questions on-site (see Figure 3b). The reasons seem to stem from subjective preferences ascribed to the individual student's personality:

> *love the chat, as I find myself asking questions more which I never would have done on-site (I'm too anxious to raise my hand in front of so many people).* [BSc student - Fall 2020]

> *The on-site would be easier to ask questions and have the answers shown/drawn on a chalk board. It would also enhance the social life of the students and perhaps spark discussion/exchange of ideas and learning.* [MSc student - Spring 2021]

This diversity of preferences is extremely interesting in relation to teaching and suggests that we could enhance the learning experience of some students by offering better *hybrid* lecture models or allow students to choose between online or on-site more freely:

> *I guess the ideal situation is having live-streamed on-site courses - so you can choose for yourself.* [BSc student - Fall 2020]

We summarize the insights on preference diversity as:

> **OBSERVATION 2C:** There is a diversity of student preferences: Some students find it easier to *focus* on-site, others online; similarly, some students find it easier to *ask questions* on-site, others online.

C. Changes in perceptions throughout the pandemic? (RQ3)

Figure 4a shows the **changes** in *preferences* for both *on-site* versus *online* lectures over time. We highlight that the results are based on *two* instances of the same course (BSc *and* MSc), over time. We see no changes in the preferences for on-site lectures. However, we see a slight reduction, over time, in preferences for online lectures from 21% in 2020 to 15% in 2021, but a Mann-Whitney U tests reveals that the reduction is *not* statistically significant ($z = -0.35$, $p = .73$). For exercise classes, however, we generally see a shift away from online and in favor of on-site exercises with a shift from 67% to 77% preferring on-site exercises; and from 12% to 6% preferring to attend exercise classes online (see Figure 4b). A

Mann-Whitney U-test reveals that this shift is *not* statistically significant ($z = 1.69$, $p = .089$).

> **OBSERVATION 3A:** Preferences for on-site versus online teaching/learning activities (*lectures* and *exercises*) appear to be relatively stable over time, despite prolonged exposure to the "forced online setting."

Figure 5a shows that the proportion of students mentioning that they find it easier to focus increases significantly over time for *online* ($z = -2.39$, $p = .017^\star$) and increases, but *not* significantly so for *on-site* ($z = -1.25$, $p = .21$). In contrast, Figure 5b shows that the proportion of students mentioning that they find it easier to ask questions diminishes significantly over time for both *on-site* ($z = 4.09$, $p < .001^{\star\star\star}$) and *online* ($z = 2.05$, $p = .04^\star$). Since this data is based on *open answers*, we cannot make conclusions about the total amount of students who experienced these phenomena, however, we assume that the descriptions are representative of the students who found the factors remarkable enough to report on them. This means, that in 2021, more students generally found it worth reporting on their ease of focus—if nothing else, this shows that more students *reflected* on how different teaching settings supported their focus. Furthermore, by 2021, more students may have developed routines and home-environments better tailored to the online study setting, and thus discovered advantages (or disadvantages) of this setting *compared* to on-site teaching, which was the norm up until early 2020.

Interestingly, the opposite is the case for ease of asking questions, which fewer students reported on in 2021 compared to 2020. It could potentially be a result of online interactions becoming the norm; by 2021, most students were used to interactions in online media, and maybe found question-asking easier (either in writing, or by interrupting the lecturer).

We summarize:

> **OBSERVATION 3B:** After prolonged exposure to the "forced online setting," the number of students mentioning that they find it easier to *focus increases*, while the number of students mentioning that they find it easier to *ask questions decreases*.

VI. THREATS TO VALIDITY

First, we consider *construct* validity and threats relating to the metrics and how relevant information was measured. We then scrutinize *internal* validity and threats to the methodology and thus, in turn, to the results of the study. Finally, we ponder *external* validity and to what extent the results generalize to other contexts.

A. Construct Validity

Measuring student preferences? The main threat here is the fact that students are answering *hypothetical* questions. We quantify student preferences on a 5-point Likert scale whereby students are asked to compare a *for some of the students, hypothetical* on-site to an online version of the course. We do not believe this is a major threat as students had experienced other on-site university lectures and exercises before this course.
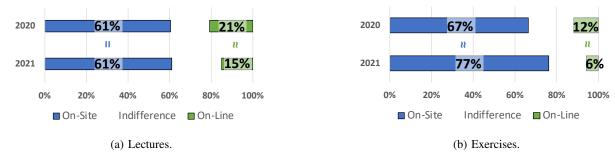
(a) Lectures.

(b) Exercises.

Fig. 4: Changes over time in the preferences for *on-site* (to the left, in blue font) versus *online* (to the right, in green font). (A tendency for *temporal stability* in preferences is indicated by an approximate equivalence symbol: '≈'.)
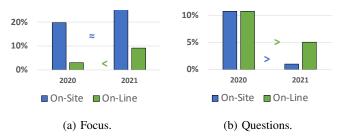

(a) Focus.

(b) Questions.

Fig. 5: Changes over time in students mentioning that it is easier to focus, respectively, ask questions on-site versus online. (A tendency for *temporal change* is indicated by '<' or '>'; A tendency for *temporal stability* is indicated by '≈'.)

How to identify advantages? To strengthen reliability [36], and in the effort to mitigate the risk of subjective data analysis [37], the qualitative data were initially categorized by one of the authors and then discussed with the co-authors in a collaborative analysis. Codes were reviewed multiple times to ensure that all important factors had been identified. This allowed for a formalization of themes that was progressively more representative of the students' response [30]. Finally, the frequencies of codes were reported to increase the transparency of the analytical process.

Measuring changes in preferences? We measure the evolution of preferences by comparing the 2020 versus 2021 surveys. For tracking preferences over time, this affords only two temporal measurements, Spring 2020 versus Spring 2021, respectively, and Fall 2020 versus Fall 2021. However, exactly these four semesters (two academic years) correlate with the entire span of the pandemic in Denmark from before until after the Covid-19 restrictions that temporarily interrupted the conventional unrestricted on-site teaching mode.

B. Internal Validity

Comparing different educational programmes? The study investigates students with different backgrounds from different types of educational programmes (both the MSc and BSc level), however, all evaluations are conducted in the context of the same course: "Introduction to Database Systems" (IDBS). It makes sense to compare aggregations of such responses

as long as they have a comparable composition (ratio of MSc versus BSc, see Section IV-C). Thus, when comparing, for instance, different teaching/learning activities (*lectures* versus *exercises*; cf. Figure 2), the results always incorporate responses from both educational programs.

Bias from imperfect response rates? There is a risk that the cohort inclined to respond to the surveys are somehow biased and not representative of all students. This would mean that the results would not necessarily generalize to all students. Considering the response rates are around half of all the students, we do not believe this to be a major threat (see Section IV-C).

Experimenter bias? In any experiment, there is a threat of the experimenter unintentionally interfering with the experiment. We mitigated this threat by phrasing and administering the questionnaires neutrally without any value judgements of on-site versus online. Throughout the courses, the teacher tried to emphasize the students take an interest in reflecting on their learning preferences. We did not examine the results of the surveys while the experiment was running.

Students interfering with the study? In any experiment involving human subjects, there is the threat of subjects interfering with the experiment. We do not consider this is a major threat since the students (nor the teacher) were not able to influence whether the course would run on-site or online; the mode of the course was governed entirely by politics (Danish government and university management) in response to the state of the pandemic.

C. External Validity

Beyond Denmark? We expect the results to generalize to regions of the world with similar educational conditions and environments; in particular, Scandinavia (cf. Section III-B). We do not expect the results to generalize to countries significantly less ready to take education online.

Beyond Databases? We expect the results to generalize to other Computing courses; especially ones that incorporate a mix of theoretical and practical teaching/learning activities (lectures and exercises), similar to the Introduction to Database Systems course surveyed in this study. After all, there is nothing inherently biased towards either physical or virtual presence in the database topic.

Beyond Computing? It is out of scope of our research to judge whether or not the results generalize beyond Computing.

Beyond the pandemic? It is of particular interest and importance to attempt to predict and foresee how the result of this study could be useful in the post-pandemic future of online teaching. We address this in our conclusion.

VII. CONCLUSION

The students of this study expressed appreciation for the quality of online teaching and materials. They also stressed their preference for on-site exercises and lectures. Some commented that they would like to keep the possibility to opt for online teaching, in case of need or for their convenience. We conclude from this study that based on the *diversity* in preferences, university didactics may benefit from more practical knowledge about *hybrid* teaching models – the optimal design of which would need to be investigated further. Based on these insights, we issue our first recommendation:

> **RECOMMENDATION 1:** In a post-pandemic future, Universities should consider using digital technology to offer a *student*-choice (as opposed to a *teacher*- or *university*-choice) of whether to participate in teaching/learning activities *on-site* or *online*, depending on individual preferences and circumstances.

This would cater to student diversity and help ensure that "the best of both worlds" (virtual *in addition to* physical). A simple approach is to conduct on-site teaching, but then have all students *also* connect to online streaming (e.g., via video conferencing). This will allow students to *also* ask questions online using the chat and to *also* see the screen on their personal computer. Of special interest to Computing, code fragments, diagrams, and other digital artifacts can be shared by the teacher, but then *also* by the students (of course, there may be some need for chat moderation which could be handled by TAs or student representatives.) In a hybrid setting where students are either on-site or online, those online have a risk of becoming a "secondary audience" with substandard representation [2]. The above mentioned approach inherently mitigates this risk.

Planning for the future of higher education though will also need to consider the lessons learned from Massive Online Open Courses (MOOCs) - tuition-free courses provided by recognized universities around the world and accessed by a large number of students [38], [39]. According to the results presented in this study and according to related work globally, in a university that operates only with online teaching, students would miss a significant part of their learning experience. They would have to develop higher self-regulative skills, find motivation, keep focus, and be able to self-assess their progress. There would also be a great impact on the social dimension of the university, on international student mobility, major financial cuts from the public sector, and negative outcomes for underrepresented or vulnerable groups of students [40]. This is why we add a second recommendation to conclude this paper:

> **RECOMMENDATION 2:** Universities need to reflect critically on the impact of the Covid-19 pandemic on their educational programs, and formulate creative and sustainable solutions for the post-pandemic future.

This entails considering the differences between emergency remote teaching and carefully planned distance education [3] and use this to re-think university pedagogical practices in a more inclusive manner [41].

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