European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceee20

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To cite this article: Tonje Jin (2022): Online interactive face-to-face learning in mathematics in engineering education, European Journal of Engineering Education, DOI: 10.1080/03043797.2022.2117023

To link to this article: https://doi.org/10.1080/03043797.2022.2117023

Published online: 03 Sep 2022.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
https://doi.org/10.1080/03043797.2022.2117023

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Online interactive face-to-face learning in mathematics in engineering education

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ABSTRACT
Online teaching has come to play an increasingly important role in higher education, especially during the Covid-19 pandemic. Being unable to be on campus with face-to-face teaching can be challenging. This article provides a possible option of how first-year engineering students at NTNU (Norwegian University of Science and Technology) adapt to mastering higher mathematics. The purpose of the research is to see whether a more 'face to face' experienced online teaching technological method will have a positive impact on student engagement, as well as exam performance. We refer to this new method as 'TeachUs' in this paper for the sake of convenience. This method gives eye contact experience for the students, which has been shown to improve engagement. The surveys of the student groups confirmed the preference of this teaching method as compared to conventional screen sharing methods.

ARTICLE HISTORY
Received 5 July 2021
Accepted 18 August 2022

KEYWORDS
Video with instructor; handwriting in mathematics; eye contact; real-time corporation; STEM learning; live streaming; multimedia learning

1. Introduction

One of the main challenges in online teaching is to find a way to keep the benefits of traditional classroom teaching. Making gestures (Singer and Goldin-Meadow 2005), being visible to the students while interacting with the content (Stull et al. 2018; Pi et al. 2020) and thus being able to provide non-verbal social cues, like e.g. body language and eye contact during the lecture (Fiorella et al. 2019) are important in order to keep the students concentrated and engaged during classes. However, these aspects are to various degrees challenging to provide in online teaching, especially in STEM (science, technology, engineering and mathematics) courses like mathematics for engineering. During the Covid-19 pandemic that affected the world during the years 2020–2022, online teaching became a new normal for most students. Both students and instructors quickly needed to adapt to online teaching methods, not surprisingly leading to several difficulties and challenges. A widely reported issue with online teaching was the lack of non-verbal student-teacher interactions like gestures and facial expressions, causing many students to perceive online teaching to be inferior to physical face-to-face teaching (Hodds 2020). Both during the pandemic and after, it has therefore been important to develop and improve solutions for online teaching.

In the current study, we present a more 'face-to-face' experienced technical method for online teaching via live streaming that maintains the important social relation between instructor and student that are associated with classroom teaching. Studies of synchronous online teaching methods have also been investigated previously, both by us and others (Jin and Wessel-Berg 2019; Francescucci and Rohani 2018). However, the main idea behind the TeachUs method is to

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make the instructor and the content display in the same window, with the content appearing in front of the instructor (Jin and Wessel-Berg 2019). The content can be in the form of digital handwriting as well as digital graphics, or several types of digital content combined (see Figure 1). This aims to create a clearer connection between the instructor and the content than in conventional online teaching methods.

The first testing by the author of displaying handwritten content in front of the instructor was performed back in 2012. At that time, the main tool was a transparent glass plate, and the method was mainly used for short videos in the Calculus course at Gjøvik University College (today a part of NTNU). The idea was mainly inspired by a picture on a website where a man was facing the camera and holding a black marker with the handwritten content appearing in front of him. Since 2015, several methods have been tried out in order to add digital content in addition to the handwritten content (2015; 2016). The current technical method is combining and adjusting several software in order to mirror digital content onto the same window along with the instructor. TeachUs is a method that is already user-friendly for the receiving end. For students who are following a live-streaming session by this method, there is no need to provide any additional hardware or software other than the most common ones used for following online lessons, like e.g. Zoom (2018), Microsoft Teams (2017) or Blackboard Collaborate (2018). It makes it easier for the students to follow the course, and for the instructor to gather feedback afterwards.

Since 2018 the method has been applied through live-streaming sessions with students in the Calculus course at NTNU. Several student groups have received live-streaming courses through this method. Some of the live streaming lectures in Zoom were recorded for later use as videos, see 2020.

The TeachUs method and its features will be more closely described later in this paper, along with a comparison with other relevant online teaching methods.

The rest of this paper is organised as follows: Section 2 provides a literature review of the main pedagogical aspects that we aim to include in the TeachUs method. In Section 3 a more detailed outline of the TeachUs method is presented. In Section 4 we present a statistical analysis of student feedback as well as exam results in order to investigate possible effects on students who

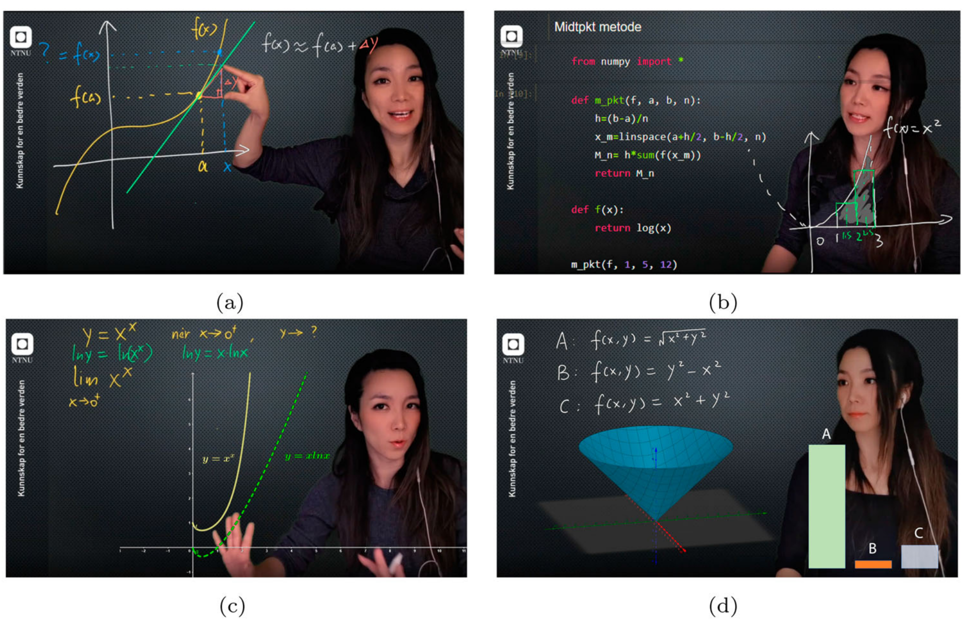


Figure 1. Screenshots from live streaming in Zoom: (a) Digital handwriting and hand-drawing content. (b) Real-time Python Jupyter Notebook and digital hand-drawing content. (c) Digital handwriting and Interactive Geogebra graph. (d) Digital handwriting, interactive Geogebra graph and polling result.

have experienced the TeachUs method. In Section 5 the results are discussed, and current challenges with the method are addressed. Finally, in Section 6 we summarise and conclude.

2. Literature review

In this section, we present a review of some of the central pedagogical aspects that are relevant for the current study. In particular, we consider the effect of visibility of the instructor, the use of gestures, the effect of eye contact between the lecturer and the students, the importance of handwriting in mathematical subjects, and interactivity between the student and the instructor. We consider the importance of these aspects for cognition and learning in general and more particularly in which way they are implemented and used in online teaching.

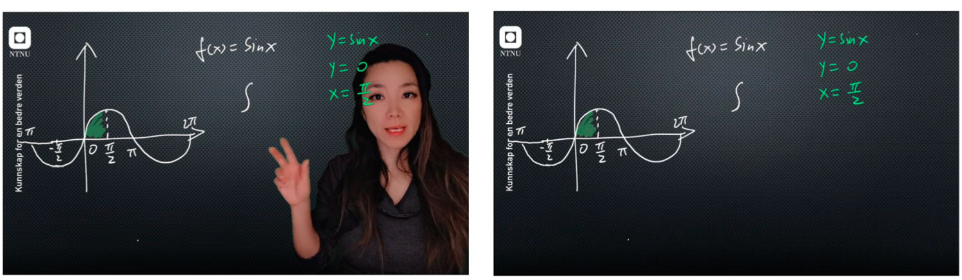
2.1. Strategic visibility of instructor

The presence of the instructor's face in video lectures has been documented to have an affective benefit among students (Kizilcec, Papadopoulos, and Sritanyaratana 2014; Persson, Wattengård, and Jacobsen 2017). The visibility of the instructor in online teaching makes it possible to provide social cues like face expressions, gestures and other body language, as well as eye contact, in much the same way as in a traditional classroom (Fiorella et al. 2019; Mayer and DaPra 2012; van Gog, Verveer, and Verveer 2014). In order to improve the students' concentration, the instructor can appear and disappear strategically during the lecture (Kizilcec, Papadopoulos, and Sritanyaratana 2014; Kizilcec, Bailenson, and Gomez 2015). That is, the instructor can be visible along with the content in parts of the lecture where body language or other non-verbal interaction with the students is important. One example is when the instructor is pointing to a part of an equation while explaining, such as the instructor would normally do while teaching in a classroom with a blackboard, see Figure 2a. On the other hand, the instructor can be absent in the parts where body language is not important, and the students instead need to have full focus on the content. This can be done when the students are given small math problems or quizzes where they need to focus, solve, and give feedback during the lecture as shown in Figure 2b.

Such strategic video presentations have been studied and found to improve the perceived social presence and reduce the cognitive load as compared to video lectures where the instructor's face was present during the entire lecture (Kizilcec, Bailenson, and Gomez 2015). The possibility of strategic visibility of the instructor is one of the key features in TeachUs.

2.2. Gestures

According to embodied cognition theory, the learning process is not solely a mental process but involves the entire body (Thelen et al. 2001; Mayer 2014). That is, students don't only learn from



(a) (b)

Figure 2. (a) Content with instructor, (b) content without instructor.

the verbal information provided by the instructor or the text they read on a slide, but also from bodily interactions. E.g. watching the instructor using gestures to explain a mathematical concept helps the students to be more attentive on the presented content. Gesturing makes the body involved in speaking and thinking about the ideas that the instructor expresses. In Singer and Goldin-Meadow (2005) the positive effect of gesturing on children's learning was demonstrated. The study indicated that gesturing provides additional information to that conveyed in speech, thus promoting the children's learning outcome, as was demonstrated in post-test results.

The effect of embodiment has been particularly demonstrated in mathematical cognition. This was investigated in detail in a study presented in Alibali and Nathan (2012). Three types of gestures were studied that 'manifest the embodiment of mathematical knowledge', namely, pointing gestures, representative gestures and metaphorical gestures. Each of these may contribute to improved visual perception for the students.

According to Alibali and Nathan (2012), by using pointing gestures, the instructor connects the spoken content and the associated mental processes to the physical content shown on the blackboard. This will reduce the cognitive load for the students and thus aid their comprehension and learning.

Representative gestures, i.e. gestures where the instructor uses his or her fingers, hands or arms to illustrate forms or figures, do also play an important role in providing additional visual perceptions of mathematical objects or ideas. One example is to use the arm to illustrate the slope of a curve, or fingers to illustrate an angle. These gestures provide the instructor's mental simulation of an action or perception. Thus, representational gestures contribute to the students' comprehension of the accompanying speech (Cook and Tanenhaus 2009; Kendon 1994).

Metaphorical gestures can be used by the instructor to visualise abstract mathematical concepts, e.g. putting two fingertips closely together to illustrate something having an infinitesimal value.

These gesture types are actively used in lectures as well as in one-on-one instructor-student interactions, and each has been evidenced to help students to more easily manage the working memory demands of mathematical thinking and learning (Alibali and Nathan 2012; Alibali and DiRusso 1999; Wagner, Nusbaum, and Goldin-Meadow 2004).

2.3. Facing with eye contact

Another aspect that helps improve the sense of social partnership between instructor and student is eye contact and the possibility for the student to follow the instructor's gaze. This helps the students motivate themselves to engage in the presented content and integrate it with their existing knowledge (Fiorella et al. 2019).

However, it is also important that the instructor periodically directs his or her gaze towards the student and the learning material throughout the lecture to provide a more engaging learning experience. It creates a feeling for the student of being seen, which establishes a social connection with the instructor, motivating the student to pay more attention to the lecture (Stull et al. 2018).

2.4. Handwriting in mathematics

The learning advantage when watching text being written or drawings being made by hand by the instructor instead of being shown pre-made static visuals has been well emphasised in the literature (see e.g. Fiorella et al. 2019; Fiorella and Mayer 2016). According to the temporal contiguity principle, the students more easily integrate what the instructor is saying and drawing when the drawings are made simultaneously with the instructor's oral explanation (Mayer 2009). This is useful in STEM courses, especially for mathematics, due to the various special symbols and expressions (Karal et al. 2015). Writing a mathematical narrative (e.g. solving equations, deriving mathematical expressions or drawing graphs) while explaining is the main pedagogical approach in teaching mathematics in primary school as well as in higher education (Artemeva and Fox 2011).

2.5. Student interactivity

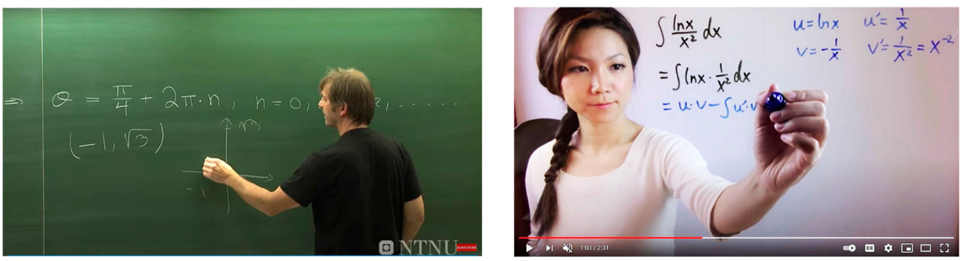
A crucial feature of live-streaming lectures is the possibility for the students to take part in dialogue and interactivity (Alexander 2004; France 2021). Examples of such interactivity are commenting via chat, polls and quizzes.

Receiving real-time questions and feedback from students is the key element to maintain the interactivity during the lecture. This is also a positive part of the conventional teaching that needs to be preserved, especially for STEM subjects such as mathematics, in which a good understanding of the previous step can affect the understanding of the subsequent steps. The ability to ask questions in real-time is one reason why live-streaming lectures are more engaging than watching pre-recorded videos.

Thus, it is important that the instructor has easy access to the equipment which provides the interactivity with students during the live streaming. In most cases, the equipment will be a computer where students' comments are displayed.

2.6. Comparison with other methods

Due to the importance of the visibility of the instructor, there are several live-streaming methods in use where the instructor is visible, and which have been investigated in the literature. We will make a brief review of the most relevant methods here.



(a) (b)

Figure 3. (a) Conventional blackboard/whiteboard, (b) transparent whiteboard.

Conventional blackboard/whiteboard: The instructor is filmed standing in front of a conventional blackboard or whiteboard. The content is provided via handwriting using chalk or a marker, see Figure 3a.

Interactive whiteboard: In this method, the instructor is filmed standing in front of an interactive whiteboard. This allows the instructor to show body gestures and facial expressions while teaching. The writing surface is a large digital board, and it looks more like a large touch-screen computer screen. The handwriting is performed by using a digital pen (Chen et al. 2020; De Vita, Verschaffel, and Elen 2018). Some representative products for interactive whiteboards are SMARTboard and Microsoft Surface Hub.

Transparent whiteboard: Here, the instructor stands behind a large panel of transparent glass facing the video camera while writing or drawing on the glass, see Figure 3b. The camera reverses the instructor's writing and drawing so that it is eligible for the audience, and the written or drawn content appears in front of the instructor. This way, the content will not be blocked by the instructor, and the instructor can face the students at all times (Stull et al. 2018; Jin and Wessel-Berg 2019; Firouzian, Rasmussen, and Anderson 2016). Thus, the instructor will also be able to use body gestures and maintain the eye contact feeling with students simply by looking at the camera. The author is quite familiar with the transparent whiteboard method after making mathematical videos with this method back in

	Blackboard/ Whiteboard	Interactive whiteboard	Transparent whiteboard	Screen sharing	TeachUs
Instructor visibility	✓	✓	✓	✓	✓
Eye-contact feeling for students	(✓)	(✓)	✓	(✓)	✓
Instructor in the same window as content	✓	✓	✓		✓
Body gestures	✓	✓	✓	(✓)	✓
Looking/pointing at the content	✓	✓	✓		✓
Digital content	(✓)	✓	(✓)	✓	✓
Body gestures with digital content		✓	(✓)		✓
Save/recall digital editable lecture notes		✓		✓	✓
Combine several digital contents in the same window		✓	(✓)	✓	✓
Combine digital content and instructor in the same window		✓	(✓)		✓
Easy to see students' comments	(✓)	(✓)	(✓)	✓	✓
Content in front of instructor			✓		✓
Digital handwriting		✓		✓	✓
Digital handwriting in front of instructor					✓
Eye contact by looking at preview					✓

✓ Yes (✓) To some degree and depending on the setup.

Figure 4. A schematic comparison between live-streaming teaching methods with visible instructor.

early 2013 (16 may 2013). Also, several non-commercial portable prototypes were made since 2015 so that other instructors could try out this method without having to build a studio (2017).

Screen sharing: By using the screen sharing function in an online communication software, the instructor shares the content while being visible for the audience via a separate window (Francescucci and Rohani 2018). The features of the various online teaching methods are summarized in Figure 4.

3. Features of TeachUs

The main feature of the TeachUs method is that the instructor appears in the same window as the content without the content being blocked. The instructor can then use body language and gestures while presenting, thus preserving positive aspects of conventional classroom teaching. The purpose is to maintain the relation between the instructor and content and thus increase the students'

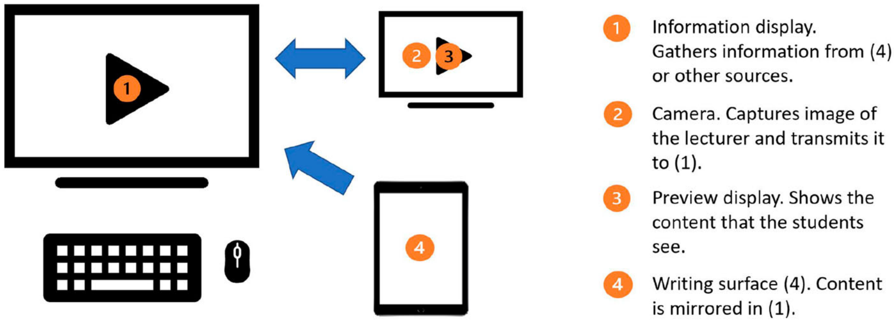


Figure 5. Simplified illustration of technical setup of TeachUs.

engagement (Fiorella et al. 2019; Kizilcec, Papadopoulos, and Sritanyaratana 2014; Fiorella and Mayer 2016).

3.1. Technical setup

In order to maintain the focus of this research article, the technical description will be kept short and simple. A more detailed account of the technical design will be provided in a future article.

A simplified schematic representation of the TeachUs setup is shown in Figure 5. In the current prototype phase, depending on the stability of the software and some other factors, the setup might vary.

The main concept is to mirror all of the necessary teaching content to the computer monitor. This is obtained by using a broadcasting software or other software that allows multiple layers with the possibility to remove a chosen colour on each layer.

Some examples of teaching content can be the camera feed of the instructor, or digital handwriting. When all the necessary teaching content is ready to be presented to the students, it can be shared via any preferred conference- or streaming software. There are also several ways to transfer the content to the conference software -- either by using a software plugin that can turn the content into a camera source that in turn can be picked up by the conference software, or by sharing the preview content using the built-in share-functionalities (i.e. 'Share contents') in the conference software.

There are plans to develop a user-friendly all-in-one TeachUs software in the near future. When several software run at the same time with special settings, as is the case in the current version, it can seem overwhelming for an instructor who is new to the method. Not to mention high requirements of the computer in order to run all the software smoothly. In addition, it is quite important to be prepared for unexpected software failures or bugs. Even a single software failure can cause interruption of the live streaming or problems with performing the lecture, so the instructor should always have a plan B prepared for each and every software that is applied. Hopefully, the new software will hopefully benefit more instructors out there who are interested in innovative and pedagogical online teaching methods.

3.2. Combined software

Instead of building a massive, complex software with a wide range of functionalities that meet the needs of all instructors (which is nearly impossible), the principle behind TeachUs is to mirror the necessary software into the same canvas along with or without the instructor. Elements like toolbars and borderlines that are not relevant for the content being presented can be cropped out by the instructor in order to reduce extraneous cognitive load (Chandler and Sweller 1991; Mayer 2006), which will be beneficial for the students' processing of information.

TeachUs mirrors and combines the content layers into one image, and streams through media like e.g. Zoom, Blackboard Collaborate, Microsoft Teams or other video conference tools. As mentioned earlier, more technical details will be elaborated on in a future paper. Our focus in this article will mainly be on the pedagogical aspects of the TeachUs method.

3.3. Mirroring content

By mirroring a digital handwriting software with endless canvas, an unlimited writing space is available, and by scrolling up and down the instructor can easily navigate.

By mirroring content from a digital real-time corporate writing/drawing tool such as e.g. Microsoft Whiteboard, the instructor and the student can write on the same canvas. From the student's view, what the student has written appears in front of the instructor along with what the instructor is writing. Thus, the student can get interactive with the instructor during the tutoring, and at the same time see the instructors' facial expressions and gestures while the instructor is explaining. This aims to simulate an on-campus situation where the instructor sits right by the student, and they can point/draw/write on the same notebook. This can, in particular, be useful in one-on-one tutoring, when the students want to show the instructor what they have done and the instructor can write/draw on the same sheet and explain. A simple demonstration of this method is shown in 2019.

In addition to having the handwriting content appear in front of the instructor, the TeachUs method also allows the instructor to mirror any of the other software content that are running on the computer. The software can be mirrored one at a time or combined. In most STEM online lectures, especially mathematics, there is often a need to display a figure or a graph along with written theory or equations. In order to demonstrate an advanced figure/plot while at the same time explaining the theory related to it, one will usually have to display it in two separate windows. The instructor will then have to jump back and forth between the theory-window and the figure/plot-window. This might feel distracting for both students and the instructor, and it will be more challenging for the students to follow and understand the content. By combining the content of these windows and at the same time keeping the instructor visible, the connection between the content and the instructor is maintained, and the students can see both parts of the content without unnecessary distractions.

3.4. Eye-contact

The TeachUs method allows the instructor to create an eye contact feeling for the students. In online teaching, the instructor is usually looking directly at the camera when talking to the students. This often results in the instructor losing sight of the contents while looking at the camera. When using the TeachUs method, the instructor creates the eye contact feeling by looking straight at his/her own eyes at the display with student-view (that is, the video image the students see while they are following the lecture). When the instructor looks at other parts of the content in student-view, it will also appear for students that the instructor actually does look at that part of the content. The actual camera remains more or less invisible for the instructor. So the instructor does not need to be aware of the camera, and will always have a good view of the content and at the same time maintain the eye contact feeling for the students. This allows the instructor to monitor what the students see at all times.

4. TeachUs evaluation

During the years the live-streaming method with TeachUs has been developed and tried out, feedback from students have been gathered via written surveys and oral interviews. The method was applied throughout several math courses. This involved more than one hundred engineering students at NTNU, in addition to a small group of cadets at the Norwegian Military Academy in Oslo.

The presented surveys were carried out in order to map which aspects of the method work well and what can be improved, and to compare the students' experience of this method to other online teaching methods.

The aim of the first survey was to investigate the students' general opinion of the TeachUs method and to receive suggestions for further improvements. The second survey aimed to compare the students' satisfaction and engagement in two parallel math classes in the same course, one in which the TeachUs method was used, and the other in which conventional screen sharing was used.

Both surveys were voluntary and anonymous, so that the students should feel free to give sincere, unbiased feedback, and also that their responses would more accurately reflect their actual opinions.

In addition to these surveys, oral interviews with students were performed with several student groups in the earlier stages of the method development.

4.1. Survey 1 -- general feedback on TeachUs

4.1.1. Participants and design

This survey was aimed to gather the students' general opinion on their experience with the TeachUs method in live streaming, and what they felt was positive compared to other online teaching methods they know about. A total number of 86 (out of 160 registered students) participated in the survey, which consisted of three questions. The participants were from the 2020-classes in the courses 'Pre-calculus' (REA0012), 'Mathematical methods 1' (IMAG1001) and 'Mathematical methods 1 for the Norwegian Military Academy' (VB6100).

Both REA0012 and IMAG1001 are originally on-campus courses. In 2020 all lectures in these courses were performed online due to the Covid-19 pandemic, while the exercise sessions partially took place at the campus. REA0012 is mainly required for students who are going to start at an engineering study program at NTNU through the alternative admission, while IMAG1001 is the first mandatory math course for all first-year engineering students at NTNU. VB6100 is originally taught partially online and partially on-site in classrooms at the Norwegian Military Academy. In 2020 the entire course was held online.

The questions asked in the survey were:

Q1: 'How satisfied are you with this teaching method, where the content appears in front of the instructor on a scale from 1 (very dissatisfied) to 5 (very satisfied)?'
Q2: 'What do you find positive with this teaching method (compared to other digital teaching methods you have seen)?'
Q3: 'Any suggestions for improvement of this method?'

Questions 2 and 3 were optional. In these questions, the students were asked to give a written response.

4.1.2. Results from survey question 1

According to the survey, 98% of the participants from the REA0012 class were satisfied (i.e. gave the rating 4 or 5) with the TeachUs method, and 90% gave the highest rating.

In the IMAG1001 class 100% of the participants were satisfied (i.e. gave the rating 4 or 5) with TeachUs, and about 95% gave the highest rating.

Also in the VB6100 class, 100% of the participants were satisfied (i.e. gave the rating 4 or 5) with TeachUs, and 67% gave the highest rating.

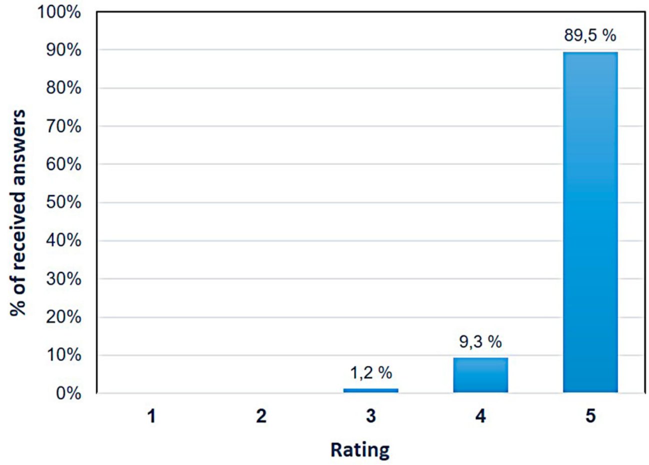


Figure 6. Overall results from survey question 1.

When we summarise the results for all of the three classes, 98.8% of the participants on the survey (i.e. 85 out of 86) were satisfied with the TeachUs method (i.e. gave the rating 4 or 5), and 89.5% gave the highest rating. The overall mean rating was 4.88 ($s = 0.35$). The results are illustrated in Figure 6.

4.1.3. Feedback from survey questions 2 and 3

In total, 50 students provided feedback on question 2, all of which were positive.

The essence in most of the comments was that the students found the lectures to be more personal and engaging when they could see the instructor using body gestures in the same window as the content. It was also commented that the students felt more present in the lectures compared to other online teaching. Thus, the written feedback indicates that the TeachUs method largely fulfils the pedagogical aims and intentions described in this article. That is, the students do experience the lectures to be more engaging, they do experience a closer relation to the instructor, and they find it easier to connect the oral and the written/displayed content.

The students were also asked to suggest any potential improvements on the method (question 3), but no concrete suggestions were given since most were satisfied with the method as it is.

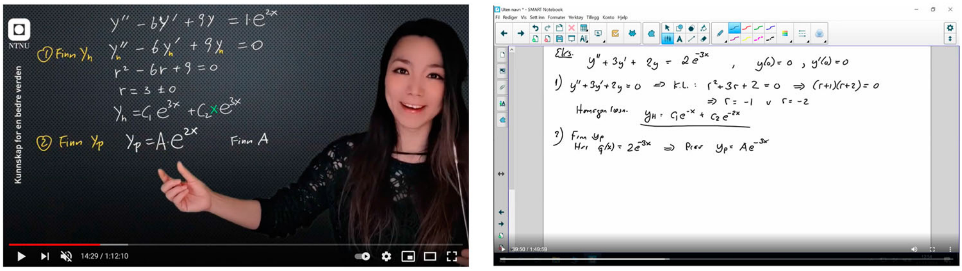
4.2. Survey 2 -- TeachUs vs. screen sharing

4.2.1. Participants and design

A total of 114 students from the target groups participated in the second survey. This survey was performed for first-year engineering students taking the course 'Mathematical methods 1' (IMAG1001) at NTNU in Gjøvik in the fall semester of 2020.

The aim of this survey was to compare and analyse the students' satisfaction and engagement in two parallel math classes in the same course, one in which the TeachUs method was used, and the other in which conventional screen sharing was used. In addition to the survey, we also analysed the attendance and activity during lectures throughout the semester as an additional measure of the students' engagement and motivation.

All of the lectures in the course were performed via online streaming due to the Covid-19 pandemic. The students were divided into two parallel classes. The classes had exactly the same curriculum and progress plan. They had access to the same common resource room in the course learning management system Blackboard (2014). The common resources included recorded course lectures both from the previous year and from other campuses. Both classes contained a



(a) (b)

Figure 7. (a) TeachUs with instructor visible, (b) screen sharing without instructor visible. Images taken from videos that were recorded during the live streaming. Both lectures are showing an example of how to solve a nonhomogeneous second-order linear equation with exponential function. Both instructors mainly used digital handwriting while teaching.

mix of students from various engineering programs like construction, mechanical, electrical, and renewable energy, so the students in each of the two classes had quite similar overall study schedules and workload. Each class had three lectures per week, with the same time schedule. Therefore, the students only had the possibility to follow the live-streamed lectures in one class at a time. Attendance at the lectures was not mandatory. The students were well informed about which class and which instructor they were assigned to on their schedule.

One class was taught by the author using TeachUs, while the other was taught by another instructor from the mathematics group at NTNU in Gjøvik using screen sharing, see Figure 7.

The instructor in the screen sharing class had long experience in both campus and online teaching, particularly with the screen sharing method. Thus, both of the instructors were experienced in online teaching.

The links for each of the live-streaming lectures were shared with the students via the common Blackboard room for the course, so that only students and instructors in the course had access.

The survey was provided to the students at the end of the semester. Most of the questions were related to general evaluation of the course. Three of the questions were intended to provide a general comparison for the analysis.

These three questions were:

Q1: ‘How satisfied are you with the learning outcome in the lectures on a scale from 1 (very dissatisfied) to 5 (very satisfied)?’
Q2: ‘How often did you participate in the live streaming lectures?’
Q3: ‘What percentage of the exercises from the textbook have you done?’

The students started by answering which class they were originally assigned to, and then which live-streaming class they actually followed. They were also asked to answer how often they attended each of the three lectures every week.

In addition to the received feedback on the survey questions, we also present some additional data in order to analyse the student engagement in the two classes, namely the actual attendance at the online lectures in the TeachUs class throughout the semester, and the number of comments that the students posted in the chat during the lectures.

Of the 114 students who participated in the survey 50 (out of 142 registered students) were from the screen sharing class, 47 (out of 68 registered students) were from the TeachUs class, while 17 students answered that they had followed both classes (11 from screen sharing class, and 6 from TeachUs class). In order to get a clear comparison of the groups, we will mainly focus on the 97 students who followed one particular live-streaming class.

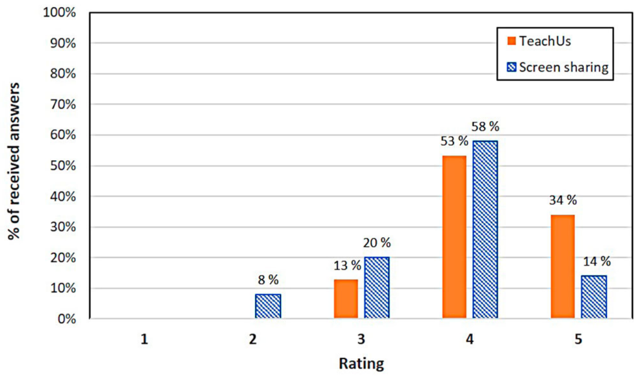


Figure 8. Results from Q1: 'How satisfied are you with the learning outcome in the lectures on a scale from 1 (very dissatisfied) to 5 (very satisfied)?'.

Table 1. Mean ratings and standard deviations for grade of satisfaction measures by two groups in Q1 on a scale from 1 (very dissatisfied) to 5 (very satisfied), as well as the *p*-value from the Wilcoxon Mann–Whitney test.

	TeachUs			Screen sharing			WMW
	$\bar{x}$	s	N	$\bar{x}$	s	N	p
Satisfaction	4.21	0.65	47	3.78	0.78	50	.007

4.2.2. Survey question 1

The first question we investigated in our analysis was: 'How satisfied are you with the learning outcome in the lectures on a scale from 1 to 5 (where 1 is very dissatisfied, and 5 is very satisfied)?'.

Figure 8 displays the grade of satisfaction distribution for each of the two classes. The results are presented in Table 1.

As seen from Table 1, the mean rating on Q1 from the TeachUs class is significantly higher than in the screen sharing class.

To compare the distribution of the satisfaction scores for the screen share and TeachUs students, the Fisher exact test gives a *p*-value of .03. Alternatively, the Wilcoxon Mann–Whitney test gives a *p*-value of .007. Choosing a significance level of 0.05, the distributions are found to be different.

However, it is not clear whether the difference in satisfaction level between the two classes was mainly due to the teaching method or due to the skills and popularity of the instructors.

Previous studies have shown strong correlations between the students' course satisfaction and the students' instructor satisfaction (Chitkushev, Vodenska, and Zlateva 2014).

According to the written feedback at the end of the survey, the students reported that they felt it was easier to follow the lectures when the instructor could use body gestures while presenting, and they could get the eye contact feeling. The instructor's enthusiasm and interactivity level during the lecture are also important factors that can affect the students' motivation level, attendance and engagement in class. It might also be a factor that the students found this new method interesting and thus got more motivated to follow the course.

Another factor that might have affected the results, is that the students of the TeachUs class attended the pre-calculus course (REA0012) during the summer, so they were already familiar with the instructor and the TeachUs method before the IMAG1001 course.

4.2.3. Survey question 2

Several previous studies have shown the importance of student attendance in education (Chen and Lin 2008; Landin and Perez 2015). Therefore, we also wanted to examine the difference in the students' attendance rate in each of the classes, both self-reported and measured, in order to investigate the students' motivation and commitment.

Attendance in the live-streaming lectures was not mandatory, and all the students had the same access to the recorded video lectures for this course.

Both classes had live-streaming lectures at the same time of the day on Mondays, Thursdays and Fridays. The students were asked about their attendance for each of the three weekdays.

Q2: 'How often did you participate in the live streaming lectures?'

with the following alternatives for each of the three weekdays:

- Does not fit
- Rarely/never
- Sometimes
- Often
- Every time

Each year, some of the senior students retook the course in order to pass the course or to improve their grade. Not all of these had a time schedule that fit perfectly with the Calculus course. The choice 'Does not fit' was given, so that we could defer these students from students who rarely attended due to other reasons.

The results are presented in Figure 9.

The students in the TeachUs class reported a significantly different overall attendance rate than the screen sharing class for the three days (p-values .0003, .0002, .0002, from Fisher's exact test). As seen in Figure 9, a total of 99% of the students in the TeachUs class reported that they attended the lectures often or every time, while the corresponding percentage in the screen sharing class was 73%.

The students who answered 'Does not fit' or 'Rarely/never' were asked to elaborate in a follow-up question. Most answered that they did not feel the live-streaming lecture provided any more learning value than the recorded videos, so they would rather watch the videos than attend the live-streaming lectures. No students from the TeachUs class answered 'Does not fit' or 'Rarely/never'.

In addition to the self-reported feedback on attendance in this survey, we investigated the recorded attendance on each of the lectures in the TeachUs class. The numbers are

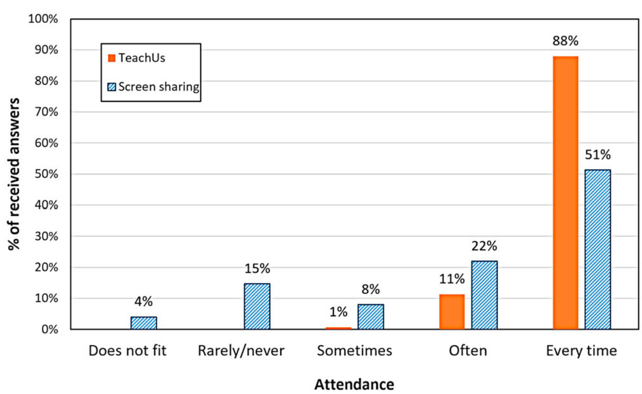


Figure 9. Results from Q2: 'How often did you participate in the live streaming lectures?'. The percentages presented in the figure are averaged over all of the three weekdays.

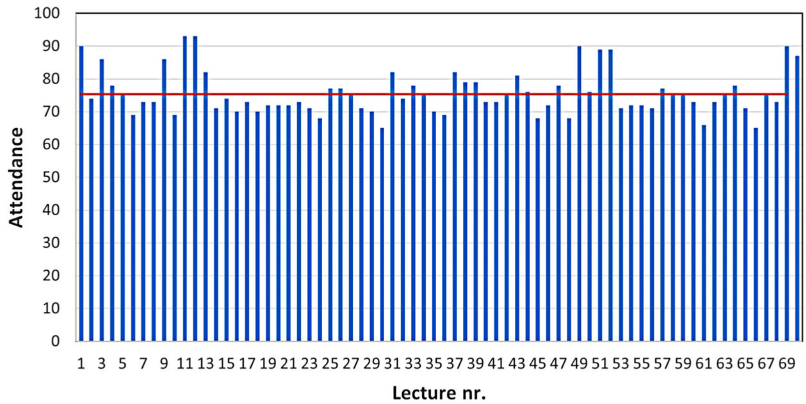


Figure 10. Number of attendants in each of the 45-minute lecture blocks in the TeachUs class. The horizontal line indicates the mean attendance ($\bar{x} = 75.4$).

provided by the video-conference software Zoom, which was used for all of the live-streaming lectures.

There were in total 35 on-schedule live-streaming lectures during the semester. Each lecture consisted of two blocks of 45 minutes with a 15-minute break in between. The streaming was usually stopped just before the break and then started again right after the break. This then provides information on attendance before and after the break. The attendance for each lecture is shown in Figure 10. In one of the lectures, the streaming was not stopped during the break. Therefore, lectures no 11 and 12 are registered with the same number of attendants.

Figure 10 shows that there was a quite consistently high attendance in the TeachUs class throughout the semester ($\bar{x} = 75.4$, $s = 6.4$), especially considering that the total number of students originally assigned to the TeachUs class was 68.

We also looked into the difference in attendance before and after the lecture breaks, to see if students would rejoin the lecture after the 15-minute break. It was found that most students chose to rejoin after the break. The mean decline in the number of attendants in the second half of the lectures relative to the first half was 3.6 ($s = 4.4$), and p-value .0004 (t-test). The paired differences in number of attendants after the break minus before the break for each lecture were approximately normally distributed according to an Anderson–Darling test for normality, p-value of .08, motivating the use of the t-test.

In some cases, the attendance was higher in the second half than in the first. A likely reason for this might be that two of the three lectures each week started at 8:15 a.m. Since some students found it hard to get up early in the morning, they joined after the break.

Anecdotal evidence from fellow educators suggests that attendance levels during the semester are typically declining, at least within mathematics classes at universities of which the author has direct knowledge and some registered data by some other educators (McKee 2000). It is therefore considered a good sign that the class with TeachUs maintained a high and stable attendance level throughout the semester.

4.2.4. Survey question 3

In order to investigate if the online teaching methods could be related to the students' work motivation, they were asked the following question:

Q3: 'What percentage of the exercises from the textbook have you done?'
with the following alternatives:

- Less than 20%
- 20–40%

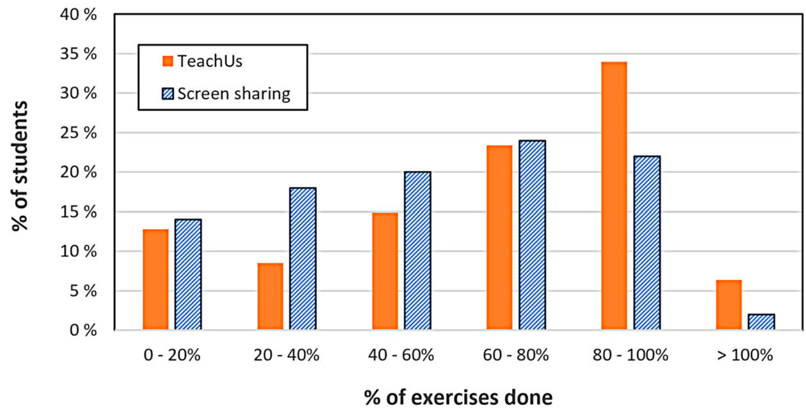


Figure 11. Results from Q3: 'What percentage of the exercises from the textbook have you done?'.

- 40–60%
- 60–80%
- More than 80%
- More than 100%

where the last alternative means that they did extra exercises in addition to those from the textbook. The results are shown in Figure 11.

The results show a tendency that students in the TeachUs class did more exercises than the screen share class, but the distribution of the percentages of exercises done is not significantly different between the two classes (*p*-value .52, Fisher's exact test).

Student engagement might have an effect on these data. E.g. that students who feel more engaged in the live-streaming lectures are more motivated to do exercises. Other factors, like e.g. how often the students are reminded about where they are in the curriculum, and listing the exercises that belong to the curriculum in this lecture might also affect the results. However, it is hard to measure these factors.

Among the students who were offered to take survey 2, 21 also participated in survey 1. Of these, 20 gave the rating 5 (i.e. the highest rating) on Q1 (how satisfied they were with the TeachUs method), while one student gave the rating 4. Also, all of these 21 students left positive comments on question 2, i.e. what they find positive with TeachUs compared to other digital teaching methods they have seen.

The results presented from this survey all indicate that the TeachUs method has a positive effect on the students' motivation and commitment in the course. However, there are other factors than the technical teaching methods that play an important role in order to engage and motivate students, like e.g. how engaging the instructor is, how the instructor follows up the students, and various other underlying factors. The effect of these factors will be investigated more comprehensively in a future study.

It would also have been interesting to compare the results of the final exam in the two classes, but due to the Covid-19 pandemic the final exam in 2020 was given as a digital home exam with auto-grading, and pass/fail as results. Therefore, the exam results were not deemed useful for a further analysis here.

4.3. Student engagement

There are several other factors than the use of the TeachUs method in live streaming that might have affected the students' attendance. One possible factor is interactivity with the students during the lecture. One of the most obvious differences between live-streaming lectures and the recorded

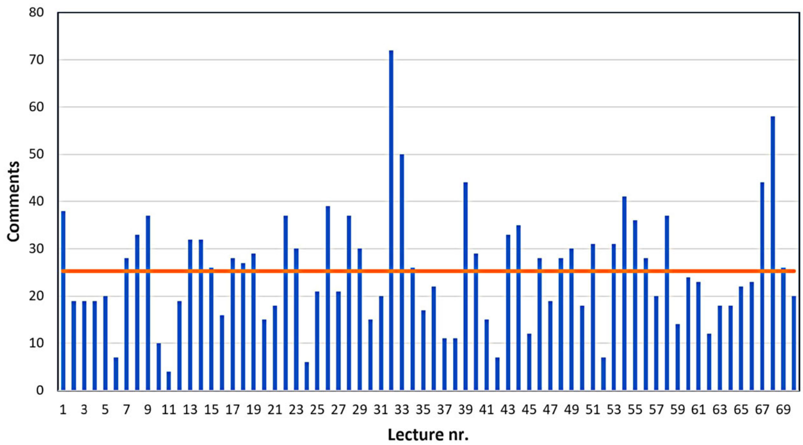


Figure 12. Number of comments in each of the 45-minute lecture blocks in the TeachUs class. The horizontal line indicates the mean number of comments ($\bar{x} = 25.3$).

videos is that the students have the opportunity to be simultaneously interactive with the instructor. One way to indicate the engagement and commitment of the students during the lectures is to look at the number of comments that the students post in the chat. Most of the registered comments are feedback from students after the instructor asked a question to the class. The registered data from the TeachUs class are shown in Figure 12.

The variation in the numbers of comments in Figure 12 might depend on the type of question asked by the instructor. In addition to commenting in the chat, several interactive methods were used in order to maintain the engagement during lectures, depending on the subject and the question type. One of the most used methods was to make the students use non-verbal feedback in Zoom where there is an option where the students can answer by clicking yes or no. This is an efficient way to obtain feedback from the students, but it is unfortunately not possible to save the number of these types of feedback in Zoom. Therefore, the non-verbal feedback is not included in the number of comments shown in Figure 12.

The large number of comments in lecture no. 32 and no. 68 were due to many questions from the instructor during the lectures that required the students to provide verbal feedback (rather than just using the yes/no-option).

4.4. Oral feedback from interviews

The TeachUs method was also tested in the course Calculus (REA1141) in the fall of 2018 in additionally offered online supervision sessions during the repetition period before the final exam. About 10 students participated in these sessions, and each student was given one-on-one supervision. In addition, the method was used in exercise sessions in the course Mathematical methods 2A (IMAG2031) and Mathematical methods 2A for the Norwegian Military Academy (VB6105) during the spring semester of 2020.

After each of these sessions, the students were interviewed and asked to provide feedback on their experience of the teaching method (e.g. problems with delay or other technical issues). Another purpose of these interviews was to gather information about which software and hardware the students used during these sessions. Feedback were given orally at the end of the online sessions.

The feedback from the participants were all positive. All the students expressed that they were satisfied with the supervision sessions. Several of the participants commented that the method looked ‘futuristic’ and that the interactive canvas possibility with the instructor made ‘a great improvement for learning and understanding’.

4.5. TeachUs vs. on-campus teaching

4.5.1. Comparison of examination performance

By comparing and analysing the examination performance, we have investigated how the TeachUs method affected the student performance relative to on-campus lectures in the pre-calculus course (REA0012).

Pre-calculus is a math course newly reformed from 2019. It is held for 10 intensive weeks in the summer. Students need to pass the final exam in this course in order to get admission to subjects like e.g. Calculus for engineering. In both 2019 and 2020 the exam was arranged in cooperation with another campus at NTNU holding the same course. The difficulty level of the exercises for both exams was intended to be similar in both years.

In 2019 the entire course was taught on campus, while in 2020 all lectures were online. The tutoring classes were both online and on campus. The on-campus lectures were held in an auditorium with blackboard (without streaming), while the online lectures in 2020 were live-streamed in Zoom with the TeachUs method. The lectures were not recorded in any of the years.

In both years the course had the exact same curriculum and progress plan. The students had access to the same learning material. Also, the difficulty level on the final exam was similar. In both years the final exam was held on-campus with pen and paper. The classes consisted of students who were going to start on an engineering study program at NTNU through the alternative admission. The author was course coordinator and taught about 80 % of the lectures in both years.

In this article, the comparison will mainly be based on examination performance and a short comparison on satisfaction level from a survey. Since 80% attendance is the minimum required to sit for the final exam, we have not compared the attendance rate in these two years.

As shown in Table 2, the 2020 class (TeachUs) had a significantly better exam performance than the 2019 class (Blackboard). Also, the average score in 2020 is 9.07 percentage points higher than the average score in 2019.

A factor that might have affected the final exam performance in these two years is that, since the course was newly reformed in 2019, it will need time for adjustment for the instructors in the new course. Another factor might be that in 2020, the students were offered to join online exercise classes via Teams in addition to exercise classes on campus throughout the course. In order to get more efficient online help in exercise classes, most of the students shared their exercise solutions in the software OneNote via Teams, where both the instructor and the students are able to edit. This might have motivated the students to do more exercises during the course.

4.5.2. Comparison of student satisfaction

Furthermore, we performed a comparison of student satisfaction in both the pre-calculus course (REA0012) and Mathematical methods 1 (IMAG1001). Like pre-calculus, Mathematical methods 1 was also taught on-campus with blackboard in 2019, while it was taught online using the TeachUs method in 2020. The author performed all lectures in both years. No changes in the curriculum and progress plan were made between the two years. This course was also intended to be included in the comparison of final exam performances, but because of the Covid-19 pandemic the final exam for IMAG1001 in 2020 was performed as a digital home exam with pass/fail as mentioned earlier, so it is hard to compare the examination performance between 2019 and 2020 in this

Table 2. Mean values (and standard deviations) of the examination scores in percentage for classes 2020 (TeachUs) and 2019 (Blackboard).

	TeachUs			Blackboard			*t*-test
	$\bar{x}$	s	N	$\bar{x}$	s	N	p
Exam score	63.31	21.37	79	54.24	20.26	59	.013

Note: TeachUs and Blackboard examination scores were approximately normally distributed (Anderson–Darling normality test *p*-value .10 and .13, respectively).

Table 3. Mean values and standard deviations of the grade of satisfaction for classes 2020 (TeachUs) and 2019 (Blackboard) in courses pre-calculus (REA0012) and Mathematical methods 1 (IMAG1001), on a scale from 1 (very dissatisfied) to 5 (very satisfied).

	TeachUs			Blackboard			WMW
	$\bar{x}$	s	N	$\bar{x}$	s	N	p
REA0012	4.50	0.68	58	4.58	0.61	51	.52
IMAG1001	4.21	0.66	47	4.53	0.76	37	.009

course. In both courses, the students were asked how satisfied they were with the lectures through a voluntary, anonymous survey. Thus, we could compare the satisfaction level in the courses between the two years. As mentioned under the analysis of survey 2, the students were asked how satisfied they were with the lectures. For comparison of TeachUs and Blackboard the Wilcoxon Mann–Whitney test was used. The results are shown in Table 3.

The results show that the students were satisfied with the lectures they received in both years. The lectures on campus with blackboard had a slightly higher average rating than the online lectures with TeachUs. However, the *p*-values indicate that the difference between TeachUs and Blackboard in REA0012 is not statistically significant. On the other hand, the differences are clearly more statistically significant for IMAG1001.

This indicates that the satisfaction level in REA0012 might be more affected by the instructor than by the teaching method, as discussed previously. Also, the students being able to attend the lectures physically in a class rather than sitting on their own in their homes in front of a computer screen is likely to contribute to the students' social well-being.

5. Discussion

The TeachUs method provides the inclusion of several beneficial aspects from traditional classroom teaching into online teaching, and it offers more instructor-student interactivity possibilities than any other existing live-streaming teaching method (see Figure 4). The ability for the student to 'interact' with the instructor while at the same time seeing the presented content (e.g. digital handwriting or images/figures) is particularly beneficial in mathematics and other STEM subjects, as discussed in Section 2. TeachUs thus addresses one of the main reported issues with online teaching, namely that students lack a feeling of non-verbal interaction with the instructor as compared to physical face-to-face teaching (Hodds 2020).

As the results from Survey 2 showed, the class being taught with the TeachUs method out-scored the class being taught with conventional screen sharing both in satisfaction level, attendance and the amount of exercises done throughout the semester.

Several possible factors in addition to the teaching method that might have affected the results, e.g. the instructor's engagement, teaching skills, etc. were pointed out and discussed in the previous section. Nevertheless, the generally very positive feedback on the TeachUs method from Survey 1 clearly indicates that it is well perceived by the students, so we can therefore argue that it likely has a significant impact on the presented results.

It should also be taken into consideration that there are possible positive synergies between students' satisfaction, attendance, work motivation and exam results. For instance, previous studies in the literature have pointed to attendance in class as an important factor affecting both the students' own feeling of learning outcome as well as performance (Anthony 2000). To summarise, the presented survey results generally indicate that the students prefer the TeachUs method over more conventional screen sharing methods in digital teaching. However, the surveys do not make it clear whether the student satisfaction, attendance and performance were mainly due to the method itself, or due to other factors like e.g. the instructor's pedagogical skills, enthusiasm, body language, etc. Further studies are thus needed in order to obtain more conclusive comparisons between the digital teaching methods, and to more clearly determine which factors have the most impact on student satisfaction. The scope of this article is primarily to present and give an overview of the TeachUs method, along with evaluations from students.

5.1. Future development of the TeachUs method

The main challenge with the current method is on the instructor's side. Displaying content in front of the instructor isn't yet a widely used method in online education. Some of the likely reasons might be that there is a special requirement for such kinds of online teaching methods, both regarding the equipment setup and the adapting of the method by the instructors.

For instance, for most instructors, it is natural to sit right in front of the camera when performing online teaching. However, if the instructor places him-/herself on the side instead of in the middle, the content can be more in focus. Furthermore, when the instructor appears as the background of the content, it is important that the content colours (i.e. the colour of the handwriting) stand clearly out from the background. This adapting challenge was evident both in the author's early transparent whiteboard approach (see Figure 3(b)) and in the latest software approach (see Figure 1). However, every teaching method will require time and practice to get used to. Even the most conventional blackboard teaching needs some adjusting and practice to be optimally performed.

As mentioned in Section 3.1, it is likely that TeachUs can become a user-friendly all-in-one software in the near future. Also, it will possibly become a built-in function in an existing conference software. In general, there has been a great development of conference software in the recent years, but the main trend has been improvement of the window sharing opportunities and the video feed quality separately. There have been developed possibilities for adding image- and AR-effects in the video feed, but there has not yet been any function for adding/combining the shared-window feed with the camera feed. Allowing the combination of the video feed with the shared window might be the next big innovative development for conference tools. It will not only be a step forward for an engaging online teaching, but also e.g. for more engaging business presentations.

6. Conclusions and outlooks

In this paper, we have presented the TeachUs method, a framework for online teaching which aims to improve the face-to-face experience for the students as well as maintaining several other beneficial aspects of classroom teaching, particularly in STEM courses.

The students for whom this method has been tested so far have provided very positive feedback. The comparative analysis of the TeachUs method and screen sharing showed that the TeachUs method received a higher rating in satisfaction from students. It also indicated a positive impact on the students' attendance and their general motivation to do textbook exercises. The comparative analysis with TeachUs vs. on-campus blackboard lectures on the examination performance showed that the TeachUs class achieved a higher average examination score.

It is possible that our study is limited to demonstrating the comparative effectiveness of TeachUs method and other methods when it comes to achieving basic educational outcomes. A future study focused on relatively higher order learning outcomes might reach different conclusions than this study regarding the effectiveness of different modes of course delivery.

Also, a more extensive study of the TeachUs method is being planned, in which we will investigate the use of the method more thoroughly. We plan to continue using the method in math courses at NTNU and subsequently make analyses that will shed further light on several aspects of the method.

Acknowledgments

I want to thank my supervisors Frode Rønning and Dag Wessel-Berg for giving constructive feedback on this article, Per Harald Ninive for contributing to the testing of this online teaching method and sorting of the analysis data, Mette Langaas for helping with the statistical analysis and giving constructive feedback, Hans Petter Hornæs for contribution in analysing the survey data, and several other colleagues at the Mathematics group at NTNU in Gjøvik for being so supportive.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Tonje Jin is an assistant professor who has over 10 year's experience in teaching mathematics for engineering education at the Norwegian University of Science and Technology. In addition to mathematics and pedagogy, she also has a background in digital media. Her current research interest is student active learning and how to combine mathematics and digital tools in a way that can increase student engagement in engineering education.

References

Alexander, R. J. 2004. *Towards Dialogic Teaching. Rethinking Classroom Talk*. Cambridge: Dialogos UK.

Alibali, M. W., and A. A. DiRusso. 1999. "The Function of Gesture in Learning to Count: More Than Keeping Track." *Cognitive Development* 14: 37–56.

Alibali, M. W., and M. J. Nathan. 2012. "Embodiment in Mathematics Teaching and Learning: Evidence From Learners' and Teachers' Gestures." *Journal of the Learning Sciences* 21: 247–286.

Anthony, G. 2000. "Factors Influencing First-Year Students' Success in Mathematics." *International Journal of Mathematical Education in Science and Technology* 31 (1): 3–14.

Artemeva, N, and J. Fox. 2011. "The Writing's on the Board: The Global and the Local in Teaching Undergraduate Mathematics Through Chalk Talk." *Written Communication* 28 (4): 345–379.

Blackboard Collaborate. 2018. "Blackboard Collaborate: A Virtual Classroom for Collaborative Learning." http://www.blackboard.com/online-collaborative-learning/virtual-classroom.aspx.

Blackboard Learning Management Systems and Software. 2014. "Blackboard Learn: A Virtual Learning Environment and Learning Management System." http://www.blackboard.com/

Chandler, P., and J. Sweller. 1991. "Cognitive Load Theory and the Format of Instruction." *Cognition and Instruction* 8 (4): 293–332.

Chen, I.-H., J. H. Gamble, Z.-H. Lee, and Q.-L. Fu. 2020. "Formative Assessment with Interactive Whiteboards: A One-Year Longitudinal Study of Primary Students' Mathematical Performance." *Computers and Education* 150: Article ID 103833.

Chen, J., and T. Lin. 2008. "Class Attendance and Exam Performance: A Randomized Experiment." *Journal of Economic Education* 39: 213–227.

Chitkushev, L., L. Vodenska, and T. Zlateva. 2014. "Digital Learning Impact Factors: Student Satisfaction and Performance in Online Courses." *International Journal of Information and Education Technology*4 (4): 356–359.

Cook, S. W., and M. Tanenhaus. 2009. "Embodied Understanding: Speakers' Gestures Affect Listeners' Actions." *Cognition* 113: 98–104.

De Vita, M., L. Verschaffel, and J. Elen. 2018. "Towards a Better Understanding of the Potential of Interactive Whiteboards in Stimulating Mathematics Learning." *Learning Environments Research* 21: 81–107.

Fiorella, L., and R. E. Mayer. 2016. "Effects of Observing the Instructor Draw Diagrams on Learning From Multimedia Messages." *Journal of Educational Psychology* 108 (4): 528–546.

Fiorella, L., A. T. Stull, S. Kuhlmann, and R. E. Mayer. 2019. "Instructor Presence in Video Lectures: The Role of Dynamic Drawings, Eye Contact, and Instructor Visibility." *Journal of Educational Psychology*111 (7): 1162–1171.

Firouzian, S., C. Rasmussen, and M. Anderson. 2016. Adaptations of Learning Glass Solutions in Undergraduate STEM Education. The XIX Annual Conference on Research on Undergraduate Mathematics Education, Pittsburgh, PA, USA.

France, A. 2021. "Teachers Using Dialogue to Support Science Learning in the Primary Classroom." *Research in Science Education* 51: 845–859.

Francescucci, A., and L. Rohani. 2018. "Exclusively Synchronous Online (VIRI) Learning: The Impact on Student Performance and Engagement Outcomes." *Journal of Marketing Education* 41 (1): 60–69.

Hodds, M. 2020. "A Report into the Changes in Mathematics and Statistics Support Practices Due to Covid-19."

Jin, Tonje. "Tonje Jin's YouTube channel", YouTube, 16 May 2013, https://www.youtube.com/channel/UCcnPRyTXUmv9Hcp8VeVmugg/.

Jin, Tonje. "Radian - En liten intro", 2015. YouTube video, 1:31, https://youtu.be/QZ6UkLogf0E.

Jin, Tonje. "Integrasjon – Volum – Oppgavegjennomgang", 2016. YouTube video, 5:09, https://youtu.be/vkddkLF7WfI.

Jin, Tonje. "Ja5 Simplified prototype", 2017. YouTube video, 3:31. https://youtu.be/hYxi43MwtbU.

Jin, Tonje. "Dialog", 2019. YouTube video, 1:14, https://youtu.be/tVgbMAU-Ams.

Jin, Tonje. "Repetisjon - derivasjon – Live forelesningen i ZOOM - IMAG1001", 2020. YouTube video, 1:10:34. https://youtu.be/JpTIcoPe2Z8

Jin, T., and D. Wessel-Berg. 2019. "'Teach Us', A Proposed New Tool for Online Education." In *Proceedings of the 2019 International Conference on e-Learning, e-Business, Enterprise Information Systems, and e-Government*, edited by H. R. Arabnia, A. Bahrami, L. Deligiannidis, and F. G. Tinett. Las Vegas, Nevada: CSREA Press.

Karal, H., M. Kokoc, C. Colak, and Y. Yalcin. 2015. "A Case Study on Online Mathematics Teaching with Pen-Based Technology: Experiences of Two Instructors." *Contemporary Educational Technology*6 (4): 319–337.

Kendon, A. 1994. "Do Gestures Communicate? A Review." *Research on Language and Social Interaction* 27: 175–200.

Kizilcec, R. F., J. N. Bailenson, and C. J. Gomez. 2015. "The Instructor's Face in Video Instruction: Evidence From Two Large-Scale Field Studies." *Journal of Educational Psychology* 107 (3): 724–739.

Kizilcec, R. F., K. Papadopoulos, and L. Sritanyaratana. 2014. "Showing Face in Video Instruction: Effects on Information Retention, Visual Attention, and Affect. Conference on Human Factors in Computing Systems – Proceedings. Toronto, Ontario, Canada.

Landin, M., and J. Perez. 2015. "Class Attendance and Academic Achievement of Pharmacy Students in a European University." *Currents in Pharmacy Teaching and Learning* 7 (1): 78–83.

Mayer, R. E. 2006. *Multimedia Learning*. Cambridge: Cambridge University Press.

Mayer, R. E. 2009. *Temporal Contiguity Principle*. 2nd ed. 153–170. Cambridge: Cambridge University Press.

Mayer, R. E. 2014. *Principles Based on Social Cues in Multimedia Learning: Personalization, Voice, Image, and Embodiment Principles: Cambridge Handbooks in Psychology*. 2nd ed. 345–368. Cambridge: Cambridge University Press.

Mayer, R. E., and S. DaPra. 2012. "An Embodiment Effect in Computer-Based Learning with Animated Pedagogical Agents." *Journal of Experimental Psychology: Applied* 18: 239–252.

McKee, D. "Lecture Attendance: Who Comes, Why They Come, and What it all Means." https://teachbetter.co/blog/2014/11/18/lecture-attendance/.

Microsoft Teams. 2017. "Video Conferencing, Meeting, Calling." https://www.microsoft.com/en-ww/microsoft-teams/group-chat-software.

Persson, J. R., E. Wattengård, and E. E. Jacobsen. 2017. "Investigating Learners' Viewing Behaviour in Watching a Designed Instructional Video." *Uniped* 40 (2): 129–139.

Pi, Z., K. Xu, C. Liu, and J. Yang. 2020. "Instructor Presence in Video Lectures: Eye Gaze Matters, But Not Body Orientation." *Computers and Education* 144: 103713.

Singer, M. A., and S. Goldin-Meadow. 2005. "Children Learn When Their Teacher's Gestures and Speech Differ." *Psychological Science* 16 (2): 85–89.

Stull, A. T., L. Fiorella, M. J. Gainer, and R. E. Mayer. 2018. "Using Transparent Whiteboards to Boost Learning From Online STEM Lectures." *Computers and Education* 120: 146–159.

Thelen, E., G. Schöner, C. Scheier, and L. Smith. 2001. "The Dynamics of Embodiment: A Field Theory of Infant Perservative Reaching." *The Behavioral and Brain Sciences* 24: 1–34.

van Gog, T., I. Verveer, and L. Verveer. 2014. "Learning from Video Modeling Examples: Effects of Seeing the Human Model's Face." *Computers and Education* 72: 323–327.

Wagner, S. M., H. Nusbaum, and S. Goldin-Meadow. 2004. "Probing the Mental Representation of Gesture: Is Handwaving Spatial?" *Journal of Memory and Language* 50: 395–407.

Zoom. 2018. "Video Conferencing, Web Conferencing, Webinars, Screen Sharing: Zoom." https://www.zoom.us/.