An Education Spaces Framework to Define Interactive and Collaborative Practices over the Physical-Hybrid-Virtual Continuum

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***Abstract**: A new industrial revolution is slowly affecting our social, political, economic, and cultural lives. A fusion of technologies and research is emerging within several fields such as robotics, artificial intelligence, the Internet of Things, genetics, and biology. Our current education system runs behind these complex interactions and needs students to be aware and skilled to cope with fast and disruptive changes. Universities need to find new strategies that enable them to play an active role within the global society, delivering relevant education for students to be ready for their future work-life. Adaptation and redesign of the conventional education model with AV-IT technologies are now opportune; physical and online practices are bridged through the hybrid domain. However, the primary goal must be pedagogy, focusing on student-active learning, communication and collaboration, and other 21st-century skills.*

The largest technical universities in the Netherlands and Norway, respectively Delft University of Technology (TU Delft) and Norwegian University of Science and Technology (NTNU) are continuously optimizing their campus facilities, teaching practices, and technological infrastructure. Although their prerequisites and approaches differ (2), they still experience the same challenges, especially after COVID-19. The Pandemic has rapidly pushed the universities into a scattered digital landscape, exposing sedimented university structures, vulnerabilities, shortcomings, and the need to transform attitudes, pedagogy, spaces, and technology. It has been clear that taking shortcuts from existing onsite practices with technology and digital solutions is not the solution for permanent implementation within the hybrid domain.

Experiences need to be consolidated to get a clearer picture of the challenges that come forward when entering the hybrid domain. How can we find common factors and the proper affordances to act as guidelines for a new technological and pedagogical framework that merges the continuum from the physical over the hybrid up to the virtual spaces?

This paper describes the ways of work of NTNU and TU Delft. It introduces an Education Spaces Framework with definitions for three levels of increasing interactive or collaborative education practices on the vertical axis and the three onsite, hybrid, and online domains on the horizontal axis. It examines the design of technological-pedagogical prerequisites and barriers when moving or even transforming a practice from one into the other. The combined experiences and related discussion propose the Education Spaces Framework for further study and structure the future initiatives.

Keywords: education spaces framework, onsite, hybrid, online

I. INTRODUCTION

Transfer of knowledge using technology has been around for decades within the "brick and mortar" Universities (1). Going from an overhead projector to a digital projector or chalkboard to an interactive whiteboard provides teachers and students with more options and tools. However, this is only true when they accept and perceive the deployed technology as user-friendly, efficient or useful (2,3). The paradox is that academics are not using a scholarly approach when they apply technology for their teaching. It still seems that the traditional teaching paradigm prevails due to old habits. Other structural, cultural, or practical reasons are the available education spaces that force the one-way transmission of knowledge through their design. Teachers are doing what they always have been doing. They adapt the pedagogy to this physical space, using the technology they find useful and can handle, like PowerPoint or chalkboard. Students attend and perceive a sense of presence and shared learning experience while understanding and memorizing facts for the upcoming assessment. The applied technology does not always challenge the traditional understanding of how students learn. In most cases, the teachers' technology adaption even sediments a traditional teaching performance, instead of fulfilling expectations made possible by the digital technology that university leadership or governmental digital strategies had in mind (4,5).

Nevertheless, information and communications technology (ICT) has a positive but small impact on the learning outcome (6). Considering that educational technology is a large toolbox to handle several learning scenarios distributed in time and space, it is hard to find evidence that directly influences higher education (HE). Consequently, it is not the technology that promotes the learning outcome, but the technology's implementation for scaffolding the applied pedagogy (7) and learning activity.

II. EXPERIENCES AND STRATEGIES

Both universities work hard at standardizing generic lecture halls and classrooms. Simultaneously, they develop some exciting pilots for synchronous student-active learning, collaboration, teamwork, and cross-campus activities to grasp the necessary affordances for modern education practices, be it more interactive frontal pedagogy or multi-location group practice.

2.1 TU Delft

In 2014, a Roadmap Education Spaces was proposed so that decentralized but generic teaching rooms could be brought under central management. This approach created the current pool of education spaces with central scheduling so that each faculty's cohorts could be time-scheduled optimally. Central management was and continues to be the responsibility of the Transforming Education Spaces (TES) working group. The assignment was to adapt all generic lecture halls and classrooms to contemporary standards for the four following common educational practices in a ten-year transformation plan (2015 - 2024); frontal didactics, mixed didactics, group practice, and exam administration. The guidelines and design requirements for these practices were put on paper in the Cookbook Education Spaces.(8)

Two more modern pedagogies a) collaborative practice and b) hybrid practice, were not sufficiently "matured" to establish central guidelines and requirements, so they are not yet

included in the Cookbook Education Spaces. Still, various studies are underway for collaborative practices with PhD research in the Collaborative Design Lab at the Faculty of Aerospace Engineering and a by the four Dutch technical universities joint program about Learning Spaces. For hybrid practices, an originally conceived pilot project in the Technology Room of the PULSE education building is revisited and the Dutch national Special Interest Group about Learning Spaces from SURF has taken initiative to collect experiences about hybrid practices from many higher education institutes.

2.2 NTNU

Many factors influence the development of guidelines, planning, and design requirements for NTNU education spaces. The prime strategy is that all NTNU's academic communities in Trondheim, now in dispersed locations, are concentrated into a single physical campus over the next ten years. The Norwegian State will fund new buildings totaling 92,000 square meters and modernization of up to 45,000 square meters of existing areas at NTNU. Today, NTNU has headquarters in Trondheim and campuses in Ålesund and Gjøvik. The inclusion of stakeholders from all locations is crucial to obtain a corresponding and coherent development within cross-campus courses and study programs. Projects and research within the development and use of cross-campus interactive learning spaces are running and will contribute to the long-term strategies for NTNU. (9–11)

An NTNU Teaching Excellence Program project called SALTO manages and refines a two-campus learning space for physical-virtual interaction and allows students and teachers to explore educational, methodological, and technological solutions together. Analysis of semi-structured interviews with teachers and students provides the foundation for research results, focusing on the interaction between pedagogy, space, technology, and the users. A new joint master's program in Music, Communication, and Technology (MCT) between NTNU and the University of Oslo constitutes the prime target for the SALTO project (12).

III. PRACTICES AND LEARNING SPACES

The studies from pilots of new learning spaces at both TU Delft and NTNU focus on modern teaching environments, student-active learning, teamwork, and cross-campus activities. Results will provide us with valuable insights to design solutions for on-campus, hybrid, and online learning scenarios. When combined with the guidelines and design requirements defined in the Cookbook Education Spaces, the following Education Spaces Framework appears with three levels of real-time (synchronous) education or collaborative practices, all spread over a continuum from physical, to hybrid, up to online domains. The framework holds nine different situations, each with its own definition, which is described in the following sections.

Education Spaces Framework	Physical	Hybrid	Online
Frontal Pedagogy (FP)	A	D	G
Participatory Practice (PP)	B	E	H
Joint Problem Solving (JPS)	C	F	J

Table no. 1 : Education Spaces Framework

3.1 Three Levels of Synchronous Education or Collaborative Practices on the Vertical Axis

The vertical axis of Table 1 contains three different levels of education practices. Teaching and learning happen on all levels but in different ways and different settings. The axis has a continuum for both learners and teaching staff. Students have more passive participation at the frontal pedagogy side and high-level active participation at the problem-solving end. The teaching staff's roles vary over the same continuum from teacher-centered lecturing and instruction to coaching activities up to expert analysis at a distance. Furthermore, the curriculum and its allocated resources and technologies must be available in formats adapted to the different levels.

Education Spaces Framework: Levels of synchronous education	
Frontal Pedagogy (FP)	Teacher centered
Participatory Practice (PP)	
Joint Problem Solving (JPS)	Student centered

Table no. 2 : Three Different Levels of Synchronous Interaction and Collaboration

Each level aims at education practices that fit with the learning objectives as described in the following sections.

a. Frontal Pedagogy

Frontal Pedagogy (FP) is the conventional and well-established teacher-oriented lecture with an occasional round of questions or planned moments for interaction. The lecturer elaborates over a particular topic, using a projector or display to present texts, images, animations, simulations, or videos with or without sound to make it a vivid performance.
Instructers use chalkboards to prove theorems, making formula derivations one step at a time and take students along into reasoning, structure, and method. Posing questions orally or by web-based polls or electronic response systems keeps the students on track with the subject matter.

Figure 1: Physical Space to Facilitate Frontal Pedagogy and using student response tools

b. Participatory Practice

Participatory Practice (PP) moves away from the teacher-centered lecture to a more student-oriented practice. It is about mixed practices with interactive elements to gain participation by engaging and activating the students. These practices can be discussion or debating-oriented, or more project-like, aiming at tangible results.

Instructors introduce topics to be addressed by defined and limited assignments. Students work in teams according to the given guidelines. Methods and rules are mentioned and explained before students start. If general questions come up from groups during the assignment, the instructor can do a short plenum explanation to all groups. The instructors change roles from the teacher to coach and walk along the tables to guide them.(13) Student-centered practices aim at active learning scenarios where every team member develops and utilizes their 21st-century skills to participate, contribute and work as a team(14) to solve the defined assignment.

Figure 2: Physical Space to Facilitate Participatory Practice

c. Joint Problem Solving

Joint Problem Solving (JPS) practices aim at ill-structured situations or "wicked" problems.(15–17) It is not an assignment with already known solutions; it is about process and approach and where to collect the necessary facts, figures, methods, and techniques. It is not about ways of swimming; it is about the swimming itself but in unknown waters.

Student teams work entirely independently on not-yet-existing solutions. It demands all their skills and competencies where interaction, communication, and collaboration are tested to the limits to solve a problem for a thus-far unknown situation. It is about synthesis in a very interactive, self-responsible, self-active, and self-organizing practice. Hence, only the higher

classes with last-year students can cope with such intense education practices similar to challenges in their future work environments.

Figure 3: Physical Space to Facilitate Joint Problem Solving Practice

3.2 Three Space Domains for Education Practices on the Horizontal Axis

Three different spaces or domains divide the horizontal axis. Teaching and learning happen over several domains, from onsite over hybrid to completely online practices. Each domain demands its affordances and equipment. Moreover, each domain prescribes the ways of work in one way or the other, meaning that pedagogies are bend to the given situation and its possibilities.

Education Spaces Framework	Physical	Hybrid	Online
Frontal Pedagogy (FP)			
Participatory Practice (PP)			
Joint Problem Solving Approach (JPSA)			

Table 1: Education Practices Space Domains

The following sections describe the three domains as rather defined separated spaces that facilitate the practices therein.

a. Physical Lecture Halls and Classrooms

Physical lecture halls and classrooms are standard practices for most education institutes. In the last decade, the focus is shifting from just a physical space to a more qualitative space that facilitates the education practice and delivers all the pieces in the puzzle of a good learning experience. It is not only about the projector and chalkboard as supportive tools, but about feeling comfortable, both for the lecturer as for students.

Many of these puzzle pieces contain essential qualities like good fresh air, suitable temperature, good acoustics and light conditions, comfortable chairs and desks, nice colors, and building materials. All factors that minimize concentration loss and improve attention span.

The AV designers and architects need to care about accessibility, placement of windows, display surfaces, sightlines, and readability. An excellent software called the TUDesc (TU Delft education space configurator) is a tool to set up and configure an education space. It is a simulator showing the consequences and interactions between factors like readability, sightlines, size of the display surface, building elements, and inventory.

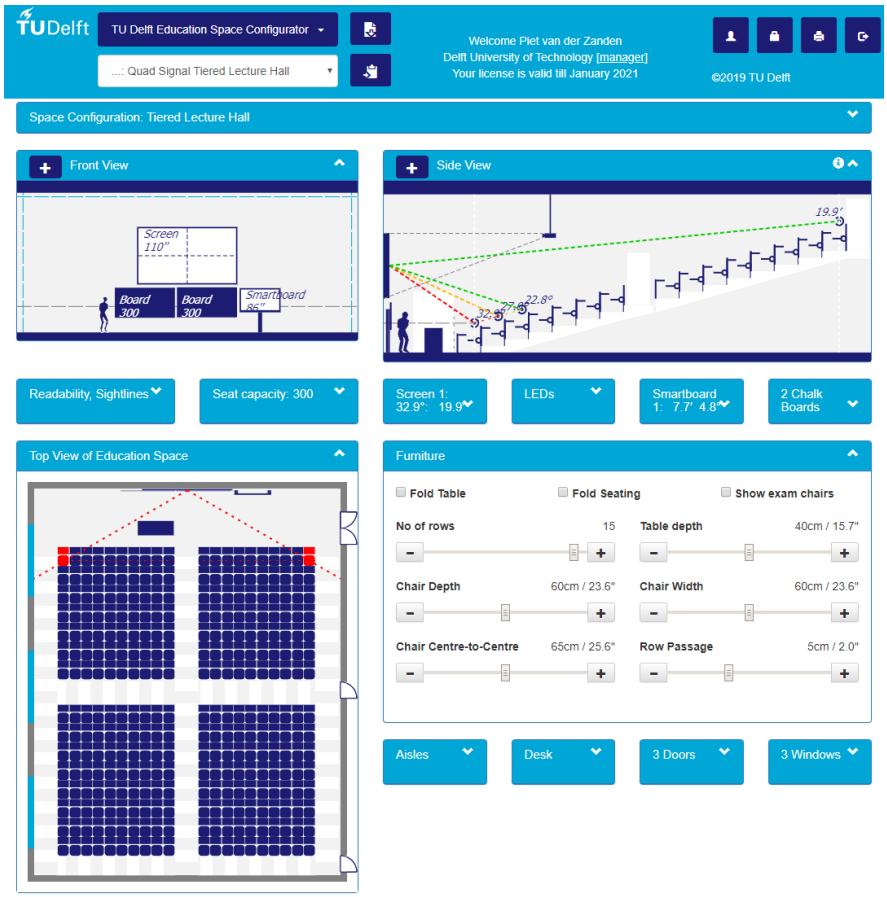

Figure 4. TUDesc tool example

In addition to the space design, the technology must support and be a pedagogical approach tool. The technology should be easy to use, and all participants should understand the usability (see and understand the value of the applied technology). Lecturers need presentation equipment that fits the practice, which works flawlessly and effortlessly to focus on the pedagogy. Providing an excellent audiovisual quality is the fundamental role of technology. Besides, technology provides equity to persons with, for instance, hearing or visual impairment. The goal is to deliver the same good quality and learning experience to all students participating in the lecture.

Both NTNU and TU Delft work hard to put all the proper affordances necessary for a specific practice, focusing on standardization and central management.

b. Hybrid Spaces to Facilitate Distributed Participants and Teams

As mentioned earlier, the quest is to deliver a qualitative physical space that facilitates the education practice and delivers all the pieces in the puzzle of a good learning experience. When we talk about hybrid spaces, we need to add several new pieces and put them into play but still try to deliver a good learning experience.

First, what is a hybrid space? It is physical spaces interconnected through technology. Whether it is two adjacent classrooms, cross-campus classrooms, or multi-location spaces interconnected, it is still an attempt to create a shared space experience by adding supporting infrastructure and technology scaffolding AV and UCC (unified communication and collaboration). In addition to the universities' interconnected spaces, there is a connection to private spaces with participating students, teachers, and experts located onsite or online attending or participating in the same shared hybrid space.

The challenge is to expand a local physical practice into a shared hybrid space and deliver a sense of shared presence to all participants. This challenge exposes one of the first pitfalls on the road to a functional hybrid space. Teachers continue to teach as they did in the physical space. The lectures are done the same way as before, with the same presentations and interaction with onsite students. There is no change or adaption of the pedagogical approach to improve remote students' engagement, participation, and learning experience.(18,19)

Several interconnecting factors are defining the type, quality, and experience of a shared hybrid space.

On the extreme side, there are two digital twins, represented by a digital and physical symmetry, where all things are mirrored and interconnected, like two control rooms talking to each other. They can control, monitor, and adjust all parameters to a total synchronized experience. Have the same temperature, air quality, same acoustics, similar room layout. These factors create symmetry and shared room experience concerning all human sensing and provide the foundation for design thinking, visual thinking, brainstorming, or any real-time team-based activity.

The connection of different types of rooms like multi-group classrooms, lecture halls, dedicated group rooms, and private spaces requires an additional layer of technology to enable audiovisual communication, collaboration, and interactivity. The university spaces may be a part of the standardization process toward a specific practice. However, each type of these physical rooms has their characteristics and features, which comes into play when they become one end of a hybrid space. The physical layout, acoustics, the extra layer of technology like displays, cameras, microphones, loudspeakers, and their placement are factors influencing the notion of presence and the overall audiovisual communication. It is vital for the teachers that the hybrid functionality is easy to use. Ideally, it creates a seamless connection between all participants enabling teamwork and shared workspaces so that teachers can focus on delivering the appropriate methods and guiding adapted to the hybrid learning scenario.

c. Virtual Spaces for synchronous Online Web lectures and Livestreams

An online synchronous space facilitates access to various resources and tools, interaction levels, communication, and collaboration. Most universities have an LMS (learning management solution), used as the framework or infrastructure for handling all aspects of the learning process. It can plan, execute and assess synchronous online learning activities and processes and create, distribute and deliver real-time education content. The LMS gives the student and teacher a shared entry point to a workspace to exchange info and schedules and act as a gateway to various virtual spaces like DLE (digital learning environment). DLE provides a combination of services and tools to support teaching and learning in an online environment. These tools and services are often interoperable and provide a secure sign-on. A collaborative learning environment (CEL) can enhance student-centered learning by applying methodologies and learning scenarios focused on peer learning and group/teamwork. Also, several other digital environments can support the synchronous online space, like the VLE (virtual learning environment). However, all these digital environments provide different entry points for students and teachers to engage in a shared virtual space, working together from anywhere.

Synchronous online spaces need to facilitate real-time human audiovisual communication, conferencing, and streaming. Platforms like Zoom, Microsoft(Teams), Google Meet, RingCentral all deliver these services. Several companies like AirMeet, lifesize, Cisco, Pexip, and bluejeans provide solutions dedicated to virtual conference systems.

Most of these systems can be defined with a basic (UCaaS) Unified Communication as a Service with a set of added features for collaboration, interaction, feedback, shared workspaces for teamwork, and online streaming. Many standalone collaboration tools & software empower students and teachers to work together from anywhere.

The end-user technology often influences the experienced quality provided by the online environment. During Covid, most students and teachers use tablets or portable computers with small-sized screens and built-in medium-quality cameras and microphones. The audiovisual quality is essential to preserve human communication, and sometimes lousy acoustics and light conditions have a negative impact. A small screen forces a layered visual distribution of tools and video-conference window, reducing several tools' simultaneous use.

IV. DISCUSSION

Many universities took a shortcut to transform their physical classes to the online domain, ensuring students could continue their learning during the lockdown. Universities did not have time to evaluate it thoroughly, and teachers decided independently and ad hoc to mirror their conventional teacher-centered practices directly online. Innovative teachers and staff took the lead and showed their colleagues how they had managed it to stick to the scheduled lectures as earlier done in the auditorium, henceforth in the online domain.

Currently, first evaluations take place to address artifacts and consequences of this mirroring, but the online-to-attend students suffer. Students' fatigue and social poverty decreased their feedback and contact with the teacher, resulting in reduced learning outcomes, lower retention rates, and reduced course completion. (20–28)

Many Universities are installing - what they describe today as - hybrid solutions. They all use the same promoting arguments: Students can attend a live lecture from anywhere. They are even proud when saying that they provide flexibility for students to stay home if they or their family are sick. However, there is a huge difference between "attend" and "participate". Attend is often described as to listen and pay attention, in other words to-be-there, while participate is to join in or involve oneself, in other words, to-be-part-of. They talk about "passive" instead of "active".

Remote students do not feel that they play their part in a shared co-learning experience when attending a mirrored lecture in the online domain. Perhaps, it is for such reason that they turn off their camera. Factors as the Zoom-fatigue (20,21) might add other reasons for such behavior to turn off cameras. Consequently, the reduction of online social interaction (black screen) enhances the feeling of being alone, even when attending an online lecture together with peers. Moreover, an instructor may feel unpleasant when the audience cameras go black one by one.

The foundations for active students to collaborate are built on a sense of co-presence, social coherence, and emotional connectedness. Staff and students need training and information about how, when, and why to prepare them while moving between the physical, hybrid, and virtual learning landscapes (25,27,29–31). Prioritizing smaller groups (social cohorts) and more extended periods in JPS scenarios and preparing students how to act within team-based group work (32) will undoubtedly help.

However, student-centered approaches come with a price in the hybrid and online learning domains when all the responsibilities rest on the teaching force. In such a case, it puts a significant load on the teacher in preparing and running participative and joint problem-solving practices. Handling new technology, multimodal communication, absorbing and providing feedback on chat, online response systems, and focusing on the lecture's presentation gives the teacher a cognitive overload. Such practices are just not sustainable when mirroring existing practices.

As a paradox, the teacher may experience quite the opposite in an online setting. Students turn their camera and microphone off, leaving even the teacher feeling alone. In the end, it seems that no one is paying attention or engaged in the online lecture. All attendants feel isolated and lonely together at the same time, in the same space, which is enforced by the applied technology.

Pedagogies must focus on keeping students attached to the given practice, whether a Frontal Practice with response systems, a Participatory Practice with central instruction and coaching or Joint Problem Solving with peer activities and expert feedback. That is not easy in physical spaces but even harder in hybrid and online domains.

Education Spaces Framework	Physical	Hybrid	Online
Frontal Pedagogy (FP)	+	0	+
Participatory Practice (PP)	+	0	0
Joint Problem Solving (JPS)	0	-	-

Table no. 4: Evaluation in Education Spaces Framework

The Education Spaces Framework shows quite ready and mature practices, marked with a "+" sign. Some practices are under investigation and tested within pilots, marked with the "**0**" sign. However, Joint Problem Solving practices within the hybrid and online domains are yet to discover, hence the "-" sign.

To identify the barriers and opportunities within these two unfamiliar practices, we need to ask a series of research questions concerning the interaction between pedagogy, space, and technology.

- What kind of impact do these transitions have on teachers?

Does it affect the teacher's performance and teaching approach? How does the teacher prepare and deliver student-centered activities and lectures compatible with different spaces and maintain the same focus on teaching and learning objectives through the domains?

- What kind of impact do these transitions have on students?

How do students experience the change of learning space? Do they feel that the transition offers a variation or a blended learning approach, accessing various dedicated tools and resources?

What kind of user-friendly technologies should be available for the teachers and students in each space/domain, and how should these learning spaces be designed?

However, the human factor is the crucial element and final piece in the puzzle, focusing on delivering student-centric learning, focusing on communication, collaboration, and other 21st skills.

- How can our domains and practices create a notion of co-presence and co-learning?
- Is the solution to facilitate more student interaction, give more feedback, and be more available for students in all domains?
- Do domains need to focus more on creating and facilitating social and informal interaction?

This paper examines the synchronous education practices, but asynchronous activities may play their part for every practice. For instance, in HyFlex solutions, offering synchronous in-class and hybrid activities and the option of joining class asynchronously through offered platforms.

Flexibility for the students is at the core of this approach. Nevertheless, the question is: How do we ensure that students feel that the choice they take offers the same experience of quality, learning outcome, and value. How do we plan these new structures, and what kind of organizational approach is required?

Can all questions be mapped into a PST framework (pedagogy, space, technology) and combined with the human element creating an overview of the complex interconnections to plan new structures and approaches by the universities' leadership?

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References

1. Muttappallymyalil J, Mendis S, John LJ, Shanthakumari N, Sreedharan J, Shaikh RB. Evolution of technology in teaching: Blackboard and beyond in Medical Education. Nepal J Epidemiol. 2016 Oct 3;6(3):588–92.

2. Granić A, Marangunić N. Technology acceptance model in educational context: A systematic literature review. British Journal of Educational Technology. 2019 Jul 9;50.

3. Abrahams D. Technology Adoption in Higher Education: A Framework for Identifying and Prioritising Issues and Barriers to Adoption of Instructional Technology. Journal of Applied Research in Higher Education. 2010 Dec 1;2:34–49.

4. Ministry of Education and Research. Digitaliseringsstrategi for universitets- og høyskolesektoren [Internet]. Regjeringen.no. regjeringen.no; 2017 [cited 2020 Mar 23]. Available from: https://www.regjeringen.no/no/dokumenter/digitaliseringsstrategi-for-universitets--og-hoyskolesektoren---/id2571085/

5. Handlingsplan for digitalisering i høyere utdanning og forskning [Internet]. [cited 2021 Mar 3]. Available from: https://www.unit.no/handlingsplan-digitalisering-i-hoyere-utdanning-og-forskning

6. Morgan K, Morgan M, Johansson L, Ruud E. A systematic mapping of the effects of ICT on learning outcomes. Knowledge Center for Education https://www forskningsradet no/siteassets/publikasjoner/1254026325690 pdf. 2016;

7. Lillejord S, Børte K, Nesje K, Ruud E. Learning and teaching with technology in higher education–a systematic review [Internet]. Oslo: Norwegian Ministry of Education and ResearchKnowledge Center for Education; 2018 p. 66. Available from: https://www.forskningsradet.no/servlet/Satellite?cid=1254035409005&pagename=VedleggPointer&target=_blank

8. Cookbook Education Spaces version 2 | Next Generation Classroom [Internet]. [cited 2021 Mar 4]. Available from: https://pietvanderzanden.weblog.tudelft.nl/2018/04/21/cookbook-education-spaces-version-2/

9. Bahmani A, Hjelsvold R, Krogstie BR. ICT-Based Challenges of Repurposing a Single-Campus Course to Multi-campus Settings: A Pragmatic Case Study. In: Pappas IO, Mikalef P, Dwivedi YK, Jaccheri L, Krogstie J, Mäntymäki M, editors. Digital Transformation for a Sustainable Society in the 21st Century. Springer International Publishing; 2019. p. 641–53. (Lecture Notes in Computer Science).

10. Hjelsvold R, Bahmani A. Challenges in Repurposing Single-Campus Courses to Multi-Campus Settings. Læring om læring [Internet]. 2019 Apr 29 [cited 2019 Nov 27];3(1). Available from: https://www.ntnu.no/ojs/index.php/lol/article/view/3033

11. Bahmani A, Hjelsvold R. From Theory to Practice: Teaching Assistants' Role in Multi-campus Education. In: Pappas IO, Mikalef P, Dwivedi YK, Jaccheri L, Krogstie J, Mäntymäki M, editors. Digital Transformation for a Sustainable Society in the 21st Century. Springer International Publishing; 2019. p. 654–64. (Lecture Notes in Computer Science).

12. SALTO project with refences to all presentations, proceedings, papers and book-chapter [Internet]. CRISTIN. [cited 2021 Mar 8]. Available from: https://app.cristin.no/projects/show.jsf?id=2044013

13. King A. From Sage on the Stage to Guide on the Side. College Teaching. 1993;41(1):30–5.

14. Schwarz R. Ground Rules for Effective Groups. The Skilled Facilitator Fieldbook: Tips, Tools, and Tested Methods for Consultants, Facilitators, Managers, Trainers, and Coaches. 2005;61.

15. Lönngren J, Adawi T, Svanström M. Scaffolding strategies in a rubric-based intervention to promote engineering students' ability to address wicked problems. European Journal of Engineering Education. 2019 Mar 4;44(1–2):196–221.

16. Lönngren J, Ingerman Å, Svanström M. Avoid, Control, Succumb, or Balance: Engineering Students' Approaches to a Wicked Sustainability Problem. Res Sci Educ. 2017 Aug 1;47(4):805–31.

17. Law V, Ge X, Huang K. Understanding Learners' Challenges and Scaffolding their Ill-structured Problem Solving in a Technology-Supported Self-Regulated Learning Environment. In: Bishop MJ, Boling E, Elen J, Svihla V, editors. Handbook of Research in Educational Communications and Technology: Learning Design [Internet]. Cham: Springer International Publishing; 2020 [cited 2021 Mar 25]. p. 321–43. Available from: https://doi.org/10.1007/978-3-030-36119-8_14

18. Ahn J. Drawing Inspiration for Learning Experience Design (LX) from Diverse Perspectives. The Emerging Learning Design Journal [Internet]. 2019 Jan 4;6(1). Available from: https://digitalcommons.montclair.edu/eldj/vol6/iss1/1

19. Raes A, Detienne L, Windey I, Depaepe F. A systematic literature review on synchronous hybrid learning: gaps identified. Learning Environ Res [Internet]. 2019 Nov 28 [cited 2020 Jan 5]; Available from: https://doi.org/10.1007/s10984-019-09303-z

20. Bailenson JN. Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. Technology, Mind, and Behavior [Internet]. 2021 Feb 23 [cited 2021 Mar 12];2(1). Available from: https://tmb.apaopen.org/pub/nonverbal-overload/release/1

21. Fauville G, Luo M, Muller Queiroz AC, Bailenson JN, Hancock J. Zoom Exhaustion & Fatigue Scale [Internet]. Rochester, NY: Social Science Research Network; 2021 Feb [cited 2021 Mar 12]. Report No.: ID 3786329. Available from: https://papers.ssrn.com/abstract=3786329

22. Pentland A (Sandy). To Signal Is Human: Real-time data mining unmasks the power of imitation, kith and charisma in our face-to-face social networks. American Scientist. 2010;98(3):204–11.

23. Støckert R, Bergsland A, Xambo Sedo A. The Notion of Presence in a Telematic Cross-Disciplinary Program for Music,Communication and Technology [Internet]. 77-101. Cappelen Damm Akademisk; 2020 [cited 2021 Mar 12]. Available from: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2684343

24. Graesser AC. Emotions are the experiential glue of learning environments in the 21st century. Learning and Instruction. 2020 Dec 1;70:101212.

25. Durlak JA, Weissberg RP, Dymnicki AB, Taylor RD, Schellinger KB. The impact of enhancing students' social and emotional learning: A meta-analysis of school-based universal interventions. Child development. 2011;82(1):405–32.

26. Rasi P, Vuojärvi H. Toward personal and emotional connectivity in mobile higher education through asynchronous formative audio feedback. Br J Educ Technol. 2018 Mar 1;49(2):292–304.

27. Weidlich J, Bastiaens TJ. Designing sociable online learning environments and enhancing social presence: An affordance enrichment approach. Computers & Education. 2019 Dec 1;142:103622.

28. New Vision for Education: Fostering Social and Emotional Learning Through Technology [Internet]. World Economic Forum. [cited 2017 Sep 28]. Available from: https://www.weforum.org/reports/new-vision-for-education-fostering-social-and-emotional-learning-through-technology/

29. Fayard A. Interacting on a video-mediated stage: The collaborative construction of an interactional video setting. Information Technology & People. 2006 Jan 1;19(2):152–69.

30. Aragon SR. Creating social presence in online environments. New Directions for Adult and Continuing Education. 2003;2003(100):57–68.

31. Kaufmann R, Sellnow DD, Frisby BN. The development and validation of the online learning climate scale (OLCS). Communication Education. 2016 Jul 2;65(3):307–21.

32. Schwarz R, Davidson A, Carlson P, McKinney S. The Skilled Facilitator Fieldbook: Tips, Tools, and Tested Methods for Consultants, Facilitators, Managers, Trainers, and Coaches. John Wiley & Sons; 2011. 574 p.