Toward Organizational Design Principles

An Explorative Interdisciplinary Case Study Investigating Digitally Supported Learning Spaces in Higher Education

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Abstract. Educational institutions are tasked with reimagining physical spaces and pedagogical methods to align with digitally supported learning environments. This study investigates the first steps of this transformation through a project on pedagogical innovations in a university setting. The research questions examined are as follows: What type of knowledge is gained from an explorative design approach to knowledge generation during educational development? How can this knowledge be presented and operationalized on an organizational level? Using a design-oriented perspective and inspiration from design-based implementation research, this study examines several activities carried out in *The Classroom of the Future* project. The activities were investigations of both existing classrooms and further possibilities within, for example, the use of active learning spaces, outdoor spaces, XR, and Sony Edge Analytics technologies. The research design incorporates both qualitative and quantitative methods. The analysis shows how strategic and operational considerations interrelate, and the findings emphasize the value of cross-disciplinary collaboration in distilling local design principles. These principles can inform the specific strategy and organization at the local university level and be inspirational for other educational institutions. The findings may be of particular interest to universities and educational programs that work within problem- and project-based learning paradigms.

Keywords: organizational design principles · cross-disciplinary collaboration · higher education

1 Introduction

In the rapidly evolving landscape of higher education, the integration of digital technologies has become a paramount concern. Educational institutions are compelled to reimagine their physical spaces and pedagogical approaches to align with the demands

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of digitally supported learning environments. The transformation necessitates a comprehensive exploration of organizational strategies and the development of design principles that can effectively accommodate and guide these changes while enhancing the students' learning experience. This research paper investigates the first steps in such a transformation, focusing on pedagogical innovations through a case study named "The Classroom of the Future", conducted at Aalborg University, Denmark.

1.1 The Context of Learning and Teaching – Research Scope and Question

The pedagogical foundation of Aalborg University (AAU) is problem-based learning (PBL), which is an educational approach that emphasizes students' active engagement in solving real-world problems to foster their development of critical thinking and problem-solving skills (Savin-Baden, 2003). Recently, the university embarked on a strategic endeavor, the PBL Digital initiative, aimed at investigating the potential of using digital tools to enhance PBL practices. As many of the students' activities in PBL are project-based, with students working on a large project, often in groups every semester (Askehave et al., 2015), the university has worked with an explicit focus on the digital transformation of problem- and project-based learning (Bertel et al., 2021). The Classroom of the Future project emerged as an integral part of this PBL Digital initiative. The overarching goal was to adapt the university's physical infrastructure to seamlessly accommodate the requirements of digitally mediated pedagogical approaches, as well as a distinct focus on classroom activities and less on individual students' group work, unless it is a part of a classroom activity.

This project was not merely about adopting new technologies but rather a more holistic approach in the intersection between technological innovations, pedagogical methodologies, and the university's overall strategic vision. The project is led by the Center for Digitally Supported Learning (CDUL) and in collaboration with researchers in digital learning technologies from the IT and Learning Design (ILD) research group and with participants from the IT department and from Campus Service. The Classroom of the Future project sought to identify how classrooms could optimally facilitate digitally supported learning. The outcome of this venture was to establish recommendations targeted at a strategic level. The recommendations focused on both general teaching spaces and specialized environments tailored to specific pedagogical and learning modalities.

This paper investigates the following research questions: What type of knowledge is gained from an explorative design approach to knowledge generation during educational development? How can this knowledge be presented and operationalized on an organizational level? This inquiry transcends technological innovations and implementations and dives into the nuanced interplay between design principles, organizational dynamics, and the strategic integration of digital learning.

This study applies a design-oriented perspective (McKenney & Reeves, 2018). The research team operated on an organizational level, culminating in recommendations that bridge both strategic and operational considerations, and is as such informed by a more DBIR perspective, that is, design-based implementation research (Fishman & Penuel, 2018). In shaping these recommendations, the team ventured beyond abstract proposals and engaged with the practical feasibility of implementation within AAU's

distinct context. The process involved an interplay between the strategic and operational levels, resulting in design solutions that resonated with the local milieu.

The findings show that this sort of research distills local design principles, which have the potential not only to inform AAU's strategic and management levels but also to permeate throughout the organization and across departments. Thus, both the process and the findings constitute the organizational design principles, and the research's interdisciplinary nature is pivotal. The collaboration between diverse stakeholders with varying expertise and perspectives fosters a knowledge repository that is not only rooted in disciplinary or domain knowledge but is also contextualized within AAU's own ecosystem. The cross-disciplinary dialog between the participants crystallized into actionable design principles that could support innovative and effective digitally supported learning spaces within the local pedagogical paradigm of problem-based learning.

This research paper provides insights into the type of knowledge generated, the concrete findings, and the design principles in the various activities carried out in The Classroom of the Future project. Findings and principles that can be relevant for other educational institutions to consider and learn from by investigating how this knowledge may translate into their own local organizations. The research thus also provides a design suggestion about a participatory and cross-departmental design process for doing such explorations of digitally supported learning spaces. By probing into the nature of the knowledge generated, its operationalization, and its interdisciplinary foundations, this study contributes to the evolving landscape of educational development and paves the way for a digitally enhanced learning environment in higher education.

1.2 A Design-Based Approach that Utilizes Interdisciplinary Collaboration

In this study, we have an inclusive understanding of what our field of research entails, encompassing both physical and digital elements, as well as participants' interactions with these elements. Thus, we identified the scope of our research as *digitally supported learning spaces*. However, as the research project is called "The Classroom of the Future," there was an institutional request to specifically investigate the physical environment. Therefore, we took an explorative approach to investigating a variety of digitally supported learning spaces focusing on the physical environment.

The study employed a design-based research approach (DBR), with a dual emphasis on comprehending and enhancing learning environments. DBR operates under an iterative and practical framework in which we conceive and refine educational interventions. These interventions are subsequently assessed within authentic educational settings (Brown, 1992). The iterative refinements of these interventions are a key feature of the process, in which the objective is that the research and development over iterations provide new knowledge and practical results (Barab & Squire, 2004; Anderson & Shattuck, 2012).

Furthermore, we are inspired by Bill Buxton's (2010) work within human–computer interaction and design orientation, which emphasizes that design, as the refinement of a single idea, may limit the discovery of new and better ways. Iteration through alternative ideas may better support this process of innovation. In our study, the iterative approach is evident, as we investigate the potential of using digital tools to enhance problem-based learning practices from different angles, contexts, and from a large variation of practice

examples. The knowledge conducted in the different phases of the research project is combined into recommendations that can lay a foundation for further iterations that expand the results to other local contexts at other universities.

Another inspiration comes from design-based implementation research (DBIR). DBIR grew out of the DBR tradition and is specifically concerned with how innovations are implemented and taken up in educational systems (Crowley, 2019). DBIR emerges from a concern that many well-researched interventions subsequently fail to produce the desired effects when employed in real-world settings (Fishman & Penuel, 2018). In response, the purpose of the DBIR initiative is to redefine the roles of researchers and practitioners. This reconfiguration aims to foster collaborations that yield innovations characterized by their efficacy, scalability, and sustainability (Fishman & Penuel, 2018).

In a study of findings and practices from existing studies and literature in educational settings (primarily schools), Jones and Harris (2014) found that social capital and professional collaboration are key factors for successful organizational change. They present how social capital is focused on facilitating collective professional actions rather than individual competencies. As mentioned in the introduction, *The Classroom of the Future* project prioritized cross-disciplinary collaboration between learning consultants, researchers, the IT department, management, and campus services to increase the chances of scalability at different levels at the university, taking different job functions and competencies into account when investigating and designing the learning spaces. Furthermore, selected rooms were tested in collaboration with teachers and students who are the daily users of the physical classrooms (see Sects. 3.1 and 3.2 on Sony Edge and Active Learning Spaces). From a DBIR perspective, we focused on identifying and negotiating problems of practice that respected the interests and experiences of practitioners, researchers, and other stakeholders (Fishman & Penuel, 2018, p. 393).

When working with results and findings in DBR projects, two dissemination strategies tend to emerge. One strategy aims to distill knowledge and results into concise, practical, and context-independent statements, often resembling step-by-step guides or if-then-do sentences. Baumgartner and Bell (2002) referred to this format as 'generative design principles.' However, as argued by Barab and Squire (2004), there is also a need for rich descriptions of the local context, the interventions, and the observations. These nuanced descriptions enable readers to comprehend the decision-making process, the reasons behind certain results, and the obstacles encountered. This knowledge can facilitate the implementation of the design in other local contexts, offering insights into where differences in context, alternative obstacles, and other factors should be considered.

As we worked iteratively with researching and improving educational settings, the investigative process involved producing demonstrable designs and changes at the local level and reflecting on their use in other contexts. The objective was to generate operational design principles for AAU, as well as insights into how these principles were reached, the pros and cons, and what to consider in the implementation phase.

2 Research Design and Empirical Methods Applied

As previously mentioned, *The Classroom of the Future* project was part of the strategic digitization efforts in the field of education (PBL Digital) set up by the AAU Digitalization Committee. The purpose of this effort was to ensure that AAU's physical framework

is capable of effectively supporting digital PBL practice. The overall project period was 2022, and the project was completed by sending recommendations to AAU management.

From the beginning, the research project was influenced by an evolving external landscape, including global supply chain disruptions, primarily due to the COVID-19 pandemic. Despite these challenges, the project adapted, and insights from comparable educational institutions that had substantial experience with digital solutions were included in the project timeline. The methodology thus evolved from its initial focus on technology piloting within AAU to a broader and more inclusive strategy that entailed visiting and interviewing other institutions, analyzing existing evaluations, and engaging in collaborative discussions across AAU departments.

DBR and DBIR are not strictly methodological recipes to follow; rather, they consist of a series of approaches (Barab & Squire, 2004) to unfold the context being examined. In this study, we used a variety of qualitative and quantitative approaches to knowledge production, such as observations, interviews, surveys, field trips, and workshops.

2.1 Project Timeline and Activities Performed

In this section, we introduce the project timeline and the activities performed throughout the study. Figure 1 illustrates the timeline of the project, showing three phases: the start-up phase, pilot phase, and analysis phase. The main activities were done in the pilot phase, which involved investigations of different physical spaces and technologies, such as:

- Investigating Sony Edge Analytics and active learning spaces, which were both used with students and teachers in several sessions, and in which we observed and interviewed participating teachers and students.
- Gathering inspiration from existing classrooms through workshops and dialogs.
- Gaining knowledge through interviews and field trips about how others—and, subsequently, AAU could—use XR in teaching.
- Investigating the potential of outdoor spaces and puzzle elements.
- Gathering inspiration from other educational institutions through interviews and field trips, particularly a long field trip to the Netherlands, where we visited three educational institutions.

As the abovementioned activities had very different characteristics, our DBR and DBIR processes relied on an array of data, and can be seen as an exploratory mixed methods design, which "*consists of first gathering qualitative data to explore a phenomenon, and then collecting quantitative data to test relationships found in the qualitative data*" (Creswell, 2008, p. 640). The data both have well-defined elements, such as interview data and observations, as well as several more fluent data types that arise from dialogs with hosts, dialogs after visits and in the transportation in-between visits, pictures taken by different participants, etc. Getting inspiration from traveling and cultural exchange is an acknowledged process for learning and creating new insights through the encounter with the "otherness" (Chemi, Jensen, & Hersted, 2015). In our analysis, we were inspired by thematic data analysis in ethnography, which "*consists of distilling how things work and naming the essential features in these in the cultural setting*" (Creswell, 2008, p. 648),

where we applied an abductive and deductive analysis approach. For each activity, we will address the specific empirical data and analytical approaches used.

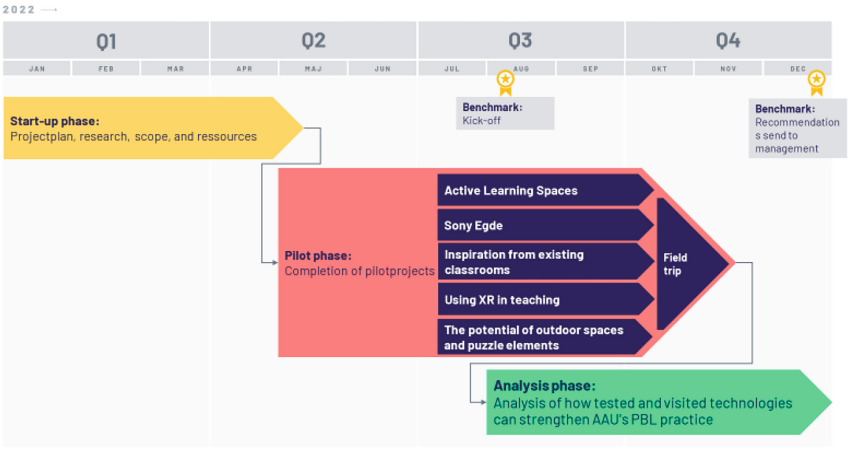


Fig. 1. The classroom of the future – Project timeline and activities

As the design-based approach progressed, it resulted in the emergence of theoretical concepts and models. References to some of these are incorporated into the description of each activity in the following sections. However, as we were interested in the perspectives of students, teachers, and the people involved from various departments, their opinions have been given room as well.

The project's activities have been assessed from a research ethics perspective and have utilized consent forms and a legal basis for data collection in accordance with the GDPR in Denmark and Europe. The research activities have been reported to the contract unit at AAU, and further information about data processing can be obtained through the contact author of the paper.

3 Project Activities and Their Analysis

This section presents the project activities, the analytical approach, and the analysis.

3.1 Active Learning Spaces

An active learning space (ALS) is a classroom "designed to support active learning and amplify its positive effects on student learning" (Talbert & Mor-Avi, 2019, p. 1). Currently, AAU has two ALS rooms with a table and screen for the teacher and 11–12 tables with a screen, each table for 5–6 students (see Figs. 2 and 3). The setup with this specific software enables the sharing of content from the teacher's screen to the screens at the student tables, where students can work collaboratively and share content with other students. The teacher can also select and share the content of one student group's screen with the rest of the groups, for example, for student presentations.

The project group tested the ALS setup to investigate the educational design and pedagogical implications. The two ALS rooms (Fig. 2) were used simultaneously for teaching a 7th semester computer science course called 'Programming Paradigms' for a two-month period with 130 students from four educational programs. In one room, the teaching was held in Danish, and in the other room, the teaching was held in English. The teacher alternated between the two rooms, accompanied by three 9th semester computer science students as teaching assistants. The students worked in groups on programming tasks, and the work was shared on all screens, enabling the teacher and students to review the different solutions in collaboration through questions and comments.

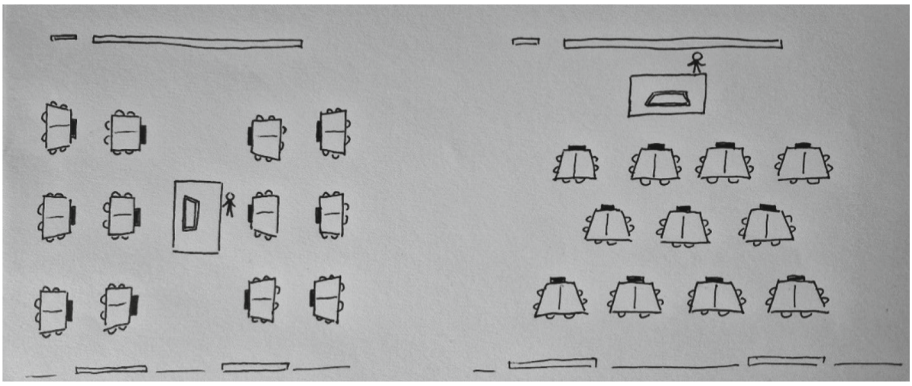


Fig. 2. The two ALS rooms

Data consisted of observations conducted on four separate occasions by the project group, a student survey with 61 replies, semi-structured interviews with the teacher and three teaching assistants, and semi-structured interviews with another teacher regularly scheduled to teach in the ALS room, who actively chose not to use the ALS setup. A deductive thematic analysis was conducted on the survey data regarding students' experiences and their perceived potential and barriers to the ALS setup. An abductive thematic analysis was conducted on data from observations and interviews regarding teacher and teaching assistants' experiences, organizational support, and the specific setup, as well as the perceived potential and barriers of the ALS setup.

Our analysis showed that the screen-sharing system proved to be valuable for plenary and group sharing, increasing transparency and enabling the teacher to better monitor student work during student presentations. The teacher also emphasized the value of the students being able to see each other's work. Moreover, the students appreciated the group tables setup but were also concerned about too little space between the tables and interruptions due to the level of noise in the room during group conversations. Other students commented on the placement of the screens in front of the tables, blocking the view of the teacher in the middle of the room (see Fig. 2). The ALS setup also enabled better use of the classroom outside scheduled classes as the layout was better suited for several students working in the room at the same time than lecture rooms. Furthermore, the analysis showed that the classrooms were mostly used without utilizing

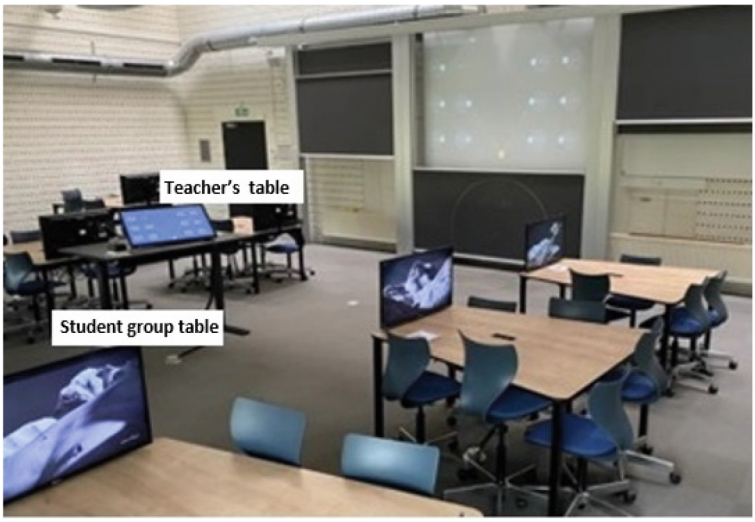


Fig. 3. The organization of tables in the active learning space

ALS technology. Outside the test, the ALS setup was used a few times, but IT support was needed for it to work. On such occasions, IT support did not feel sufficiently qualified to support the ALS setup, affirming how little the technology was used.

The ALS classrooms are owned by one department, where attempts have been made to offer teachers training in how to utilize the ALS technology and layout, but with little success, making it difficult to point to comprehensive reasons why teachers do not use the technology. A lack of interest and participation may be due to a lack of knowledge about pedagogical possibilities or a lack of perceived need or desire to change existing practices.

Although there is room for improvement, the analysis showed that when the educational design and pedagogics are aligned with the ALS technology and layout, the classrooms can support a variety of PBL activities. For AAU, this raises questions as to whether an upgraded and more flexible ALS solution should be implemented in more classrooms across AAU, who owns the rooms and how booking is handled, and how to support and ensure meaningful pedagogical practices and good use of the ALS rooms.

3.2 Sony Edge Analytics

AAU has several rooms that support synchronous hybrid teaching, combining simultaneous face-to-face and mediation via video conference/live streaming (Bülow, 2022). The current solutions make it difficult for online students to see what is written on the boards. Students have to choose between seeing the teacher or the slides, and the teacher can walk off the camera. Sony Edge Analytics (SEA) addresses some of these issues so that online participants can see the writing on the boards, see the teacher and the slides at the same time, and have a camera auto-tracking the teacher (see Fig. 4).

AAU had previously purchased and installed SEA in a few rooms and wanted to test how it could support hybrid teaching. Aiming to investigate the use of SEA in real teaching situations, four teachers agreed to test SEA. SEA was used for three lessons at the MSc in ICT, learning, and organizational change with a total of 80 students. Furthermore, SEA was used in a voluntary lesson in applied philosophy with an unknown number of students. The data consisted of observations conducted online and in class (hybrid format), a short student survey with 21 replies, and semi-structured interviews with two teachers. A deductive thematic analysis was conducted on the survey data regarding students' experiences and their perceived potential and barriers to the SEA setup. An abductive thematic analysis was conducted on data from interviews and observations regarding teacher experiences, organizational support, and the specific setup, as well as the perceived potential and barriers.

Fig. 4. Classroom with Sony Edge Analytics (notice the teacher is projected into the visuals shown on the screen – slides, video, etc.)

The analysis showed that online students were predominantly positive toward the use of SEA, as one student wrote: "I got the experience of being in the room with the teacher even though I was online. It made online teaching more dynamic and alive." For the students in the classroom, the technology became more visible, and as one student wrote, "I experienced that the technology became more of a disruptive element that day". The students in the classroom were still overall positive toward the use of SEA, which could be due to an appreciation of the online potential. The overall survey showed that students wanted more hybrid formats and pointed to a general need to improve hybrid teaching, which is in consistency with other hybrid teaching investigations at AAU (see e.g., Knudsen et al., forthcoming). Furthermore, the analysis showed challenges with the existing setup of SEA, for example, the positioning of the teacher, the direction of the teacher's gaze (see Fig. 5), and the online sound.

The teacher found it difficult to keep a simultaneous overview of both technology, students in the classroom, and online. This particular setup created many new directions for the teacher's gaze, which turned out to be disruptive for both the teacher and the students. Another challenge was that function controls were positioned far from where the teacher was positioned, making use of the technology more complicated.

Overall, the analysis showed that although the current setup requires adjusting and an extra assistant, using SEA can significantly improve the experience of being online in hybrid teaching situations.

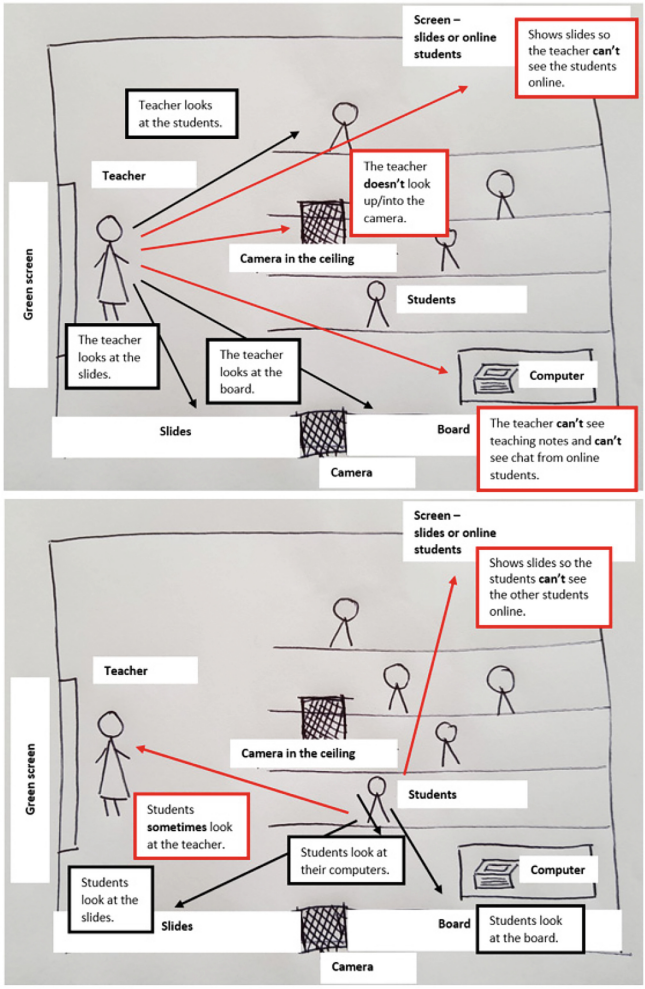


Fig. 5. Teacher's and students' gaze direction

3.3 Inspiration from Existing Classrooms

The project group entered into a dialog with AAU IT services (ITS) and AAU Campus Service (CAS) to get inspiration on how existing internal partners perceived our classrooms. After conducting an online workshop with AVDAN, an existing supplier of AV equipment, we worked with this knowledge in an online workshop with ITS and CAS, developed and facilitated by researchers from the ILD research group and digital learning consultants from CDUL.

The data from this effort consists of fieldnotes, designs developed in the workshop on realizable teaching scenarios using different technological tools, and a proposal from AVDAN on possible solutions. An abductive thematic analysis was conducted on data from the workshop, designs, proposal, and fieldnotes regarding teacher and student

experiences, organizational support, and specific setups, including the existing ALS and SEA setups, as well as the perceived potential and barriers. The workshop became both a knowledge-sharing forum between ITS, CAS, learning consultants, and researchers, as well as an opportunity for the project group to gain knowledge about existing solutions, plans, and possibilities through an explorative iterative analysis. During the project, CAS also contributed to the investigation of ALS with its own studies, supplementing the findings of the project.

Analysis of the knowledge gained from CAS, ITS, and AVDAN on the existing classrooms, the general study environment, and future possibilities pointed to several important areas, such as physical layout, light, sound, indoor climate (air, CO2 levels, and temperature), the use of plants, and issues regarding inclusion and equal access to classrooms. CAS and ITS also pointed out that it would be beneficial to focus more work in a cross-sectional manner on the physical environment in classrooms.

Among other initiatives, AAU has worked to implement uniform AV/VK solutions across the university, and investigations at AAU indicate that the teachers are very familiar with the current solutions and feel comfortable teaching in any of the classrooms because the setup is recognizable. A point to consider is that in several classrooms, the speakers, according to AVDAN, are inexpediently placed at different heights and distances. This can make those present in the room very tired, especially if the sound runs through the speakers for long periods of time. It could be remedied using an active voice lift, which can ensure that the teacher's voice is the dominant one in the room. COVID-19 necessitated ad hoc implementations that resulted in confusion regarding the setups in the classrooms, which led to a discussion on whether classrooms in the future should support hybrid teaching formats. Knudsen et al.'s (forthcoming) study, conducted at AAU in the fall of 2020, indicated that 81% of students wanted the flexibility that hybrid teaching formats offer, whereas 77% of teachers preferred to teach face-to-face. This points to the need for a strategic discussion about the use of hybrid teaching formats across the AAU. ITS continuously works to future-proof the digital solutions in the classrooms by adding more input options to the current video conference setups, making it easier to upgrade with new functionalities, such as an auto tracking camera. CAS is also currently working on implementing a digital overview by each door that shows students when classes are planned for the classrooms in question. The purpose is for students to use the classrooms for group work when the rooms are not used for teaching.

A proposal presented by AVDAN regarding ALS solutions was discussed with CAS and ITS, with a focus on the placement of the screens and the use of curtains or whiteboards as space separators, addressing some of the issues with AAU's current ALS (see Sect. 3.1). It was proposed that whiteboards as separators in the ALS classrooms would work best, as there were concerns about fire hazard, indoor climate, and students' experience using curtains.

3.4 Using XR in Teaching

As part of the study, we conducted an investigation consisting of five qualitative interviews with three international universities, a Danish university, and a Danish company, all using and/or creating XR for teaching. XR is a collective term for augmented reality

(AR), virtual reality (VR), and mixed reality (MR), as shown in Fig. 6, in which physical reality and/or objects are supplemented or replaced by a digital element across several sensory modalities.

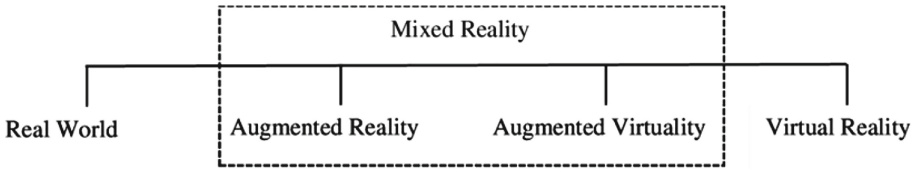


Fig. 6. Virtuality Continuum (Sünger & Çankaya, 2019, p. 118)

XR can be used to qualify and/or supplement existing teaching with XR courses (experiences, interaction, 3D models, laboratories, teaching outside the traditional classrooms, etc.) or to provide students with design skills.

Through interviews, we sought insight into the XR solutions used and the implementation and operation of these solutions, as well as insight into the pedagogical implications of using XR across various disciplines and faculties. The data consisted of field notes from five online semi-structured interviews. A deductive thematic analysis was conducted regarding various setups and types of use regarding education and intended learning goals, pedagogical and didactical implications, teacher and student experiences, and organizational support and anchoring.

The analysis also showed that there were three central conditions to consider when using XR at AAU: digital pedagogies and educational design, XR in relation to PBL, and organizational implementation. The pedagogy and educational approach depend on the type of technology used and how technology is included in teaching (Meyer, 2011). Within the context of AAU, XR has the potential to be used in PBL activities, and the investigation showed the project team that XR can be used individually, in groups, for class sizes of up to 30–40 students or large classes using open VR worlds. At the interviewed universities, the organizational implementation was primarily initiated by teachers already interested in XR, and expanding the use of XR across the organization was supported using introductions to XR and teacher assistants with XR knowledge. AAU should consider how, if, and where XR might be used, as well as whether to go for dedicated XR spaces or mobile options. AAU could also consider what resources need to be allocated for the purchase and development of solutions, contemplating that well-supported implementation requires dedicated resources (time, money, assistance) to rethinking educational designs and developing teachers' skills regarding XR from both a pedagogical and technological perspective.

Through the analysis, we identified four learning scenarios using XR, which are not mutually exclusive and can be applied crosswise: (1) having one or more rooms dedicated and furnished for the use of XR, (2) XR facilities as a library function, (3) XR integrated into specific programs, and (4) using XR for distance students.

3.5 The Potential of Outdoor Spaces and Puzzle/Riddle Elements

Through an exploratory approach, the project group sought knowledge of how outdoor spaces can be used in the learning experience through an investigation of how puzzle/riddle walks utilize, understand, and use outdoor spaces. This perspective is interesting because it challenges the classical way of thinking about learning spaces and can provide inspiration on how to conduct PBL at AAU.

The project group tested a history hunt offered by the company *HV?M* (HVEM, 2023), a company specializing in historical riddles, puzzle walks, escape rooms, and workshops for private people, as well as museums. The data consisted of observations, fieldnotes, a recorded semi-structured interview with the two founders on their use of outdoor spaces, analogue, and digital tools, and a dialog on the possibilities regarding PBL at AAU. An explorative iterative analysis was conducted regarding the use of indoor and outdoor spaces, pedagogical, and didactical possibilities, and overall potential and barriers.

The analysis showed that outdoor spaces and puzzle/riddle elements can be used in both generic and subject-specific learning scenarios, where the role of the teacher can be small (such as initiating or helping to clarify needs) or large (such as facilitating plenary dialogs and ongoing sparring in the learning process). Generic learning scenarios could be methods or techniques used across AAU, such as an introduction to AAU (history, organization, buildings), a specific institute/education, or an introduction to PBL and group formation. The use of rooms, open spaces and the outdoor in combination with puzzle elements can contribute to expanding, deepening, and supporting more informal learning situations, fostering a familiarity with the premises as well as supporting social connections among the participants. The subject-specific learning scenarios could be used as an introduction to a subject, concept, etc., in which the teacher is more of an integral part of the process. Learning scenarios using outdoor spaces and/or puzzle/riddle elements can be technical or materially complicated solutions, but it is possible to imagine simple and less technically expensive solutions. The development of the learning scenarios must consider how the solutions work with different class sizes and mobility and whether the solutions can be scaled (Hautopp, Ejsing-Duun, & Vigild, 2019).

3.6 Field Trip to the Netherlands – Findings from Three Educational Institutions

The purpose of the field trip was to find out how other similar educational institutions had chosen to set up their physical learning environments, and how they, through digital support, explored innovative designs for their classrooms. The aim was to gain knowledge of the experiences that the other universities had in developing, implementing, and operating physical and digital frameworks for what they considered to be good teaching. The commission for the project group's work was to explore the classrooms of the future from the perspective of the students, teachers, and the organization (in our case AAU). However, on a field trip where the available people were determined by the host, it was not possible to obtain the same in-depth firsthand input on all of these perspectives. Nevertheless, we had the opportunity to see a large number of different classroom setups and pedagogical approaches, including talking to experts who had knowledge of how

the students, teachers, and administrators had experienced these different settings and approaches.

All three institutions had educational ideas, culture, and dimensions that enabled the project to compare it with AAU's context. Thus, we observed and dealt constructively with potentials and barriers because some elements were comparable, but we were also inspired and challenged by other elements and conditions that were completely different. The project team especially sought to relate to how similar choices would support digital teaching and problem- and project-based learning at AAU.

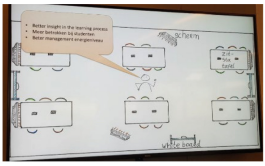
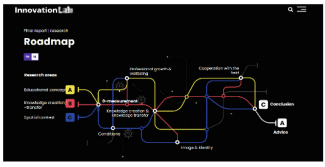
The field trip took place at the end of the pilot phase (November 2022), during which the following universities were visited:

- TU Delft, over 2 days. A university of technology and engineering
- Utrecht University, over 2 days. A general university that covers all areas of science, similar to AAU.
- FONTYS ICT over 1 day. An applied sciences institution, which is equivalent to a university college in a Danish context.

The project group invited people from various governing and subsidiary bodies at AAU on this field trip. The intention was to create a knowledge-sharing and development space, and thus to bring a wide range of experiences home to AAU. The organization of the trip meant that the project team also perceived the university we visited through "the perspectives of the invited participants." There were representatives from Campus Service, IT Support, the vice dean's office for education, and the implementation group for PBL Digital, in addition to the project group's own representation of digital learning consultants, researchers, and teachers from CDUL and ILD.

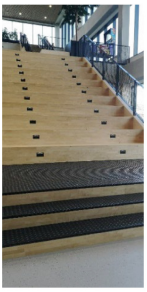
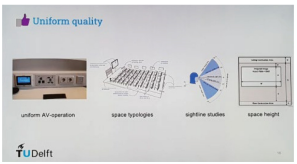
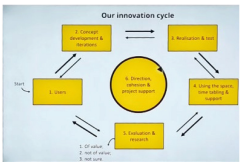
The field trip offered insights into many different types of circumstances, educational structures, etc., all of which affect how teachers and students approach new and different solutions, methods, and technical setups in a learning context. The data consisted of observations, fieldnotes, pictures, videos, materials supplied by the hosts, participation in a workshop, and dialogs among the project group, with the hosts and a few students. An explorative iterative analysis was conducted regarding inspiration and areas of interest. The first iterations of this analysis took place during the field trip and between the activities. Afterwards, an abductive thematic analysis was conducted across the three organizations regarding the topics listed below. During the field trip, many themes, experiences, and perspectives came to light and were discussed among participants. This can be condensed into multiple themes, as illustrated in Table 1.

Table 1. Themes and visuals from the field trip

Various formats for project work and teaching, with large group and team rooms, as well as active learning spaces.	 
Various formats for hybrid teaching, both in ordinary classrooms, as well as examples of using hybrid teaching formats in other types of rooms, such as the active learning space at Utrecht University (see also Future Learning Spaces, 2023).	 
Application of project oriented and student-directed approach to teaching, as the format at FONTYS ICT, which were based on challenges. Here, the physical layout of classrooms, the technological solutions, and the teacher's role were significantly redesigned.	
XR and puzzle/escape-room approaches in teaching.	 

(*continued*)

Table 1. (*continued*)

Students' own productions, for example, for project work and dissemination.  	
Teaching from studio— a 100% online participation space. 	
The large rooms— lecture rooms, in between and outdoor spaces.   	
Premises and premise planning 	Organizational change/anchoring. 

These cross-disciplinary perspectives became especially evident in our observations during the field trip. For example, Utrecht University organized an ALS room with the teacher in the middle, similar to the rooms at AAU, but with group tables placed in a circle around the teacher table. At the group tables, the students' screen was placed behind the students and not in front of the table, blocking the view of the teacher in the middle (see section ALS 3.1). This led to an interesting discussion among researchers and learning consultants, who took pictures of the arrangement of furniture and screens. From the IT department and campus service, the specific technical setup became the focus of attention as they took pictures of the placements of wires, wall sockets, etc. These different points of attention throughout the entire field trip fostered a holistic-oriented dialog that enhanced technical, organizational, and pedagogical perspectives in the resulting recommendations and the suggested organizational design principles.

4 Findings – Toward Organizational Design Principles

Based on the analysis of the project, several recommendations were presented to AAU's strategic committee for education. The organizational design principles presented in this section take their point of departure in these recommendations. Across the empirical data, we found two categories of organizational design principles: strategic and activity-based. The principles are first derived and described at the local AAU level in Sects. 4.1 (strategic) and 4.2 (activity). Section 4.3 then provides a collective summary on a more general level.

4.1 Strategic Organizational Design Principles

The strategic organizational design principles express the importance of strategic change and anchoring when working with digitally supported learning environments.

Ownership of and Booking Classrooms. Central operation, maintenance, and administrative support of classrooms are essential factors in ensuring that the educational design and pedagogical choices regarding classrooms and digital tools are supported daily. The project team recommends that classrooms that require extraordinary attention or that work significantly differently from the ordinary classrooms in a building be owned and administered by the university and not by the individual departments in the specific building.

Currently at AAU, most classrooms, including those with specific digital support tools, are owned by departments. A more central approach to special classrooms, cross departmental or even cross faculties, will work to ensure that teachers obtain the right pedagogical support and timely assistance. Departments could still be the initiators of such rooms, whether via educational programs or research groups, as people close to the subject matter may be more knowledgeable about new ways that could be tried out. However, this will require changing the internal processes for booking and paying rent for some classrooms, as well as requiring dialogs and decisions regarding how, where, and for whom rooms are booked. This will make special rooms more available, increase use, and who uses them. Currently, many programs work based on the idea that each education or module often uses the same classroom throughout a subject/semester.

This may work well for the standardized rooms but not for the specialized classrooms, colliding with AAU's policy of ensuring that rooms are fully utilized. For example, when a class is allocated to the ALS, it only applies the specific setup once or twice, or not at all.

This will require setting up a process for registration and handling requests for different types of classrooms. It also requires developing learning scenarios and PBL models geared toward the different types of classrooms to be used in the planning of various educations and subjects.

Hybrid Teaching Formats. Currently, AAU does not have a transparent and clearly communicated strategy for hybrid teaching formats. There seems to be a need for a strategic and explicit decision about whether hybrid teaching formats are used. AAU is a multi-locational university with students who live and work in various places. Further, considering the increasing interest both nationally and internationally in flexible modes of attending university, it is important that AAU supports PBL-based group lessons, regardless of students' and teachers' location. If the hybrid teaching format is to be used, which the project team recommends, the when, where, and how it should be implemented are crucial to consider avoiding ad hoc decisions or too many diverse solutions across the organization. It would be relevant to decide and communicate explicitly whether a hybrid teaching format should be an offer for students to passively log in and follow classes, or if online students should be actively included, requiring pedagogical/educational redesign. Decisions should be made regarding the necessary support (student/teaching assistants, competence development, CDUL, and IT support) and allocating time for the teachers to redesign their teaching. Although it should be a uniform decision, it does not entail that every education program should use the format. There seems to be potential related to continued education, master's programs, and when students are in internships or doing projects and thesis work, for example, in companies.

4.2 Activity-Based Organizational Design Principles

The analysis of the empirical data from the pilot projects and activities carried out in this study shows the potential for updating AAU's current digital solutions and classrooms. The activity-based organizational design principles draw on these findings and offer different solutions for AAU to consider.

Active Learning Spaces. The current ALS solution at AAU has issues regarding the maturity and practicality of the technology, and the technology takes too much of the teacher's attention and does not fully support the students' learning processes. However, ALS has the potential to work quite well with PBL activities. The focus on active learning and the students' very positive experiences make ALS a viable setup for some of the existing classrooms at AAU, which the project team recommends should be further explored. Teachers have found the current ALS rooms at AAU difficult and inflexible to operate. The ALS rooms seen during the study trip had better solutions regarding physical layout, for example, better placement of screens and tables, height-adjustable tables, mobile power, and whiteboards for shielding. Furthermore, the hardware and software used allow for a more user-friendly interface.

Similarly, it is essential that strategic investments are made in teacher training regarding ALS technologies and pedagogical applications. Upgrading the current ALS rooms at AAU might eliminate the need for assistants when used for smaller classes, but for larger classes, assistants might still be a relevant option, depending on the subject and activities. It is also important that all departments commit to testing the ALS rooms with their education and help establish a corps of ambassadors.

The project team observed how challenges can work as a type of active learning space. During the field trip, we observed how FONTYS ICT applied a project-oriented approach based on challenges with little or no regular teaching. This approach is an all-encompassing model that positively impacts both student well-being and employability, according to FONTYS and a PhD student in her final period, who investigated the model. Students selected a challenge formulated by companies. They worked on individual learning objectives in teams of 15–20 students. That is, each team member might have different objectives, but all objectives were from the same overall education and common goals according to the challenge. Each team had a specific teacher who guided and worked with the groups. FONTYS had a large space allocated for teamwork, as well as areas for ad hoc lectures by the teacher and technological facilities to support plenary dialogs, students' own productions, screen sharing, etc. This approach shares similarities with PBL and the project team recommends that AAU discuss the possibility of carrying out a pilot study.

Teacher-Centered Activities That Applies Digital Tools. Although the SEA pilot project showed potential for teacher-centered activities, the current solution at AAU is not mature enough to be implemented across AAU on a large scale. SEA has features that were found useful, but the solution implemented currently at AAU requires that a technical knowledgeable person is present. The relevant and useful features were found to be an auto-tracking camera enabling the teacher to move freely in the classroom. Handwriting extraction augments the writing on white boards/blackboards enabling students participating online to follow what is written on the blackboard. Green screen overlay enables the teacher to be visible when presenting images, videos, or PowerPoints for students participating online. Some of these technical features are also seen in other hardware/brands, as the workshops with AVDAN, dialogs with ITS and CAS, and the field trip showed.

All these functions are useful in hybrid and online teaching formats, or when recording lectures. However, if teachers are to use these functions themselves, user-friendly solutions are needed, and preferable versions that integrate better into a standard setup. The project team recommends that AAU look into the possibilities of implementing the identified useful technical functions, preferably by updating the current standard technical setup in the video conferencing systems placed in the classrooms (in the near future, e.g., 5 years). Integrating the functionalities in AAU's existing video conferencing system ensures a well-known interface and uniform expression across AAU. Strategic investments should also be made in teacher training on how to use the new functions and provide a sandbox for exploring how to integrate functions with various pedagogical applications into their own teaching.

It is necessary that AAU has the capability to teach large cohorts of students, and AAU therefore has several large classrooms and auditoriums with space for 150–1000 students. These rooms are primarily used for classic teacher-centered activities (and for research conferences or similar events with many attendees). SEA is a technology designed to also support classical lectures and large plenary dialogs in face-to-face teaching, enabling everyone to see the content, the presenter, and follow the dialog. The project team recommends the implementation of these functions in selected rooms and that adequate technical support is present to ensure smooth operation, especially when very large assemblies of students are present.

Light, Sound, and Indoor Climate. Light, sound, and indoor climate are important parameters for ensuring the optimal conditions for learning, and collaboration with CAS and ITS showed several areas in need of investigation and improvement. Especially important is how sound, light, and indoor climate affect PBL learning activities. The following functions could be advantageously added to the current classrooms at AAU: *active voice lift* optimizing the use of sound in classrooms, amplifying the teachers' voice and filtering out noise; *light* that is suited for the learning activities and can be changed, supporting the level and nature of the activity; and CO_2 *measurements* that automatically coordinate with data and the classroom schedule listing the planned number of students, ensuring an appropriate oxygen level. The project team recommends that AAU explore these aspects and how they can be added to the technological support repertoire of all standard and specific classrooms.

Teaching Online from a Studio-Classroom. Full online participation in classes offers greater flexibility for both students and teachers. The field trip showed that teaching from a studio can offer a solution that supports equal access and participation in classes, although the specific technology/solution had maturity issues regarding implementation and support. Therefore, implementation of a studio for online teaching should focus on a solution that functions reliably and should be included in the collectively and cross department/faculty owned classrooms. Having a studio for online teaching is particularly relevant for AAU's portfolio of continued education (master's programs and short non-ECTS awarding courses), where students require more flexibility in terms of where and how they can participate in classes, enabling participation nationally and internationally in highly specialized fields of AAU's expertise. This is also relevant for education at AAU, which is offered at different geographically located campuses. The project team recommends that AAU acquire and gain knowledge and expertise in such studios.

XR, Puzzle/Riddle Elements, and Outdoor Spaces. This project found educational potential in using XR technologies, puzzle elements, and outdoor spaces for teaching and PBL activities, although the maturity of the technologies and, in some situations, their fragility is also a hindrance. XR is not yet suitable for purchase and implementation across all AAU's classrooms. Great potential has been identified in developing AAU-generic XR resources, such as introductions to AAU, academic work and PBL, or a department's educational programs and electives. In addition, AAU-specialized XR resources can be extremely relevant, as in TU Delft, where students' engineers in a specific module worked with their own ship and container designs in XR. The use of puzzle elements and outdoor spaces also requires the development of new learning designs and models but can be made at relatively low cost. Therefore, the project team recommends that AAU work more explicitly with these technologies, stay updated with the new knowledge, explore the educational designs and digital pedagogical potentials, with the objective of developing an AAU-generic XR resource for PBL that utilizes open spaces (indoor and outdoor), and support teachers who wish to explore the use of XR.

Students' own Digital Productions. The study trip showed how TU Delft and FONTYS ICT offer media studio facilities and the opportunity to borrow hardware and software in physical loan centers, enabling students to make products, use tools to collect data, and convey results by producing videos and podcasts. It is very relevant for AAU to support students' digital and non-digital productions, and although local initiatives exist at AAU, the project team recommends that such physical media production studios and a loan center be implemented and maintained with open student access in mind.

4.3 Overview

Table 2 provides an overview of the strategic and activity-based organizational design principles.

Table 2. Overview of the strategic and activity-based organizational design principles.

Suggested strategic organizational design principles

- All classrooms that are extraordinary in terms of educational design and digital pedagogical equipment, and which require guidance, knowledge, and support, are collectively and cross department/faculty owned.
- These special, centrally owned classrooms are allocated based on the educational design and digital pedagogical needs of the subject, teacher, and planned activities.
- Hybrid teaching formats are chosen as a prioritized and explicit addition to the current physical teaching practices, meaning a coherent approach, with an explicit choice of which educational programs use these formats, when, and how.

Suggested activity-based organizational design principles

- Prioritize the implementation of Active Learning Spaces (ALS), and have the solutions widely implemented within, for example, 5 years.
  - Have at least one ALS room established within each faculty and/or at each campus, even each building. Continue to explore the possibilities of implementing ALS as an addition to the current standard classrooms, but where the room's interior design and technological solutions are updated, and teachers' competences are supported.
  - Have a dialog at the management level (at the department, faculty, or board level) on whether to make pilot tests on a complete program or semesters with a challenge-driven approach to learning and teaching as a type of active learning space.
- Explore the possibility of implementing a user-friendly version of digital tools that support teacher-centered activities. The identified relevant tools are cameras that automatically follow the teacher, green screen solutions, and handwriting abilities. The functions are relevant for video conferencing, large lecture halls/auditoriums and for video recordings of lectures or similar activities, such as panel discussions and Q&A sessions.
  - If user-friendly and compatible versions of the functions are found, update the current standard technical setup in the video conferencing systems placed in the classrooms (in the near future, e.g., within 5 years) and provide teacher training and resources for exploring the new functions and pedagogies into own teaching.
  - Update (selected) large classrooms and lecture halls with these new functions and provide technical assistance (student assistance) for their use, especially when very large assemblies of students are present.
- Explore adding technological solutions such as light, sound, and indoor climate ensuring the optimal conditions for learning in all standard and specific classrooms.
- Purchase and implement a reliable online-teaching-from-a-studio solution, and gain experience from a minimum of two continued educations as well as a minimum of one ordinary education within the very near future, for example, one year.
- Investigate the pedagogical and educational potential of XR, puzzle/riddles and the use of outdoor space in learning activities with the aim of developing generic resources at the university, including:
  - Ensure a continuously updated overview of already existing XR resources at the university or via open access and take initiative to a network for knowledge sharing and cooperation for those who wish to use XR in their teaching practice.
  - Investigate and develop a PBL model pertaining to the use of XR and outdoor spaces.
- Develop, implement, and maintain physical media production studios, and a material and technology loan center for students, and perhaps organized or staffed by students.

5 Discussion, Future Perspectives, and Concluding Remarks

Design-based research takes its point of departure in wanting to investigate the real context, with all its messiness and chaos (Brown, 1992). In this project, we have rested on, to some extent, previous experiences and studies at AAU, pilot experiments (such as ALS and SEA), and other organizations' complex everyday life situations. Thus, the results are based on triangulating (Creswell, 2008) between the original educational design and the digital tools supporting this, combined with the experiences that the participants described to the project team related to evaluations and discussions with the cross-disciplinary team of people from AAU. The analysis showed that even though it is possible to learn from reading about the experiences of others, the field trip and workshops meant visiting places together and relating to them as an AAU community, which gave a nuanced perspective due to the very different backgrounds of the participants.

As mentioned, the purpose of the project was originally to acquire relevant technologies and test them in the university's own teaching context, which at AAU is based on the principles of problem-based learning (PBL). The project's purpose changed in the start-up phase, when it became clear that it was impossible to acquire new technologies within the given time frame (in the aftermath of the COVID-19 pandemic). Therefore, the purpose of the project changed to explore the potential of relevant technologies in real teaching and to learn from the practices of other educational organizations. Using the design-based implementation research perspective (DBIR in Fishman and Penuel, 2018) and the professional collaboration among disciplines for organizational change (Jones & Harris, 2014) qualified the findings from both the AAU pilot projects (ALS and SEA) and the more second-hand empirical data (the field trip, XR, and outdoor spaces, as well as workshops and dialogs about the existing classrooms and possible next steps).

The overall aim of the project was to find and identify ways of facilitating digitally supported learning in the classroom, which is why an explorative approach was applied. A more systematic data-gathering approach could have revealed other insights. For example, a study mapping the system landscape, with respect to digitalization at the educational area at AAU, found that more than 160 systems were in use, and that there were differences in attitude and use of these systems (Hougaard, 2022). This study illustrates that the current digitalization landscape is already quite complex, and that future implementation strategies should contemplate not only what to implement next, but also how to select, what not to select, and where to consolidate. The project team finds that in a future situation, with no issues in terms of acquiring the technologies, it is likely a similar strategy will be chosen. This way of looking at a number of solutions and ensuring voices from several places in the organization is an eminent way to get quick but substantial insights and enables better choices between major interventions (cf. Buxton (2010) and the importance of looking at alternative designs). Also, it is a great way to meet across departments because you relate to and speak about real-world examples, and not a laboratory experiment, and as it is outside your own organization, there is a better opportunity to express your opinion and relate to what would work or not work in one's own organization. However, this, of course, requires that everyone participating feel that they are in a safe and fruitful environment where experiences can be voiced. Another advantage is that the organization does not acquire several technologies with a number of uncertainties about the actual potential in relation to being able to support a digital

PBL practice and the AAU teaching culture. Furthermore, we argue that there is value in the project itself. The partners from CAS and ITS expressed that this was the first time they had spent so much time together hearing each other's perspectives on matters that they would have to implement from their area of expertise and learning more about how this affects the other areas. Nevertheless, if this project is to be a comprehensive and adequate DBIR project, it would require that the design principles be implemented, evaluated, and reworked.

Some of the principles are used continuously at AAU, while others are yet to be picked up. The Danish government recently announced one of the biggest reforms in the university's foundation, changing the number of programs, their scope, and their length. This means that other agendas are at the forefront of universities in general and at AAU. However, the use of active learning spaces is already spreading throughout the organization. In addition, in the specific pilot project, the project team learned from the coordinator of the module that the number of students passing the course rose significantly, from around 20% the year before to 68% when using the ALS room. The room and the digital tools themselves do not give these results, but the alignment between the room, technologies, and pedagogies used made a big difference for everyone. In the social science and humanities faculty, a new education between two Nordic universities (Finland and Denmark) is offered, and AAU has redesigned a small classroom into an ALS room at the Copenhagen campus. At the start of the fall semester in 2023, hybrid teaching formats were utilized, with the intention of this being the primary format for the entire education. There was a dialog between the project team and the people undertaking the design of this room, and some of the learnings regarding flexibility and camera auto-tracking were included. Other lessons learned, such as the placement of students' monitors, were not included in this design, as the process took place simultaneously with this project. At the Aalborg campus, in a new building housing the health faculty, larger ALS facilities (for larger classes of students) have also been created.

Our research question focused on the type of knowledge generated by the project, which is illustrated in the rich descriptions and local design principles in the previous sections. A valid criticism would be that this research-based development project is not theoretically "heavy," but it does encompass a significant amount of research-based and expert knowledge through the group members. The project group chose to prioritize rich descriptions and concrete recommendations based on the empirical data because the nuanced descriptions of local contexts offer insights into where differences in context, alternative obstacles, and other factors should be considered (cf. the introduction and the design-oriented approach used).

The results also lean toward organizational perspectives on educational design and their support through digital tools. Another perspective could have been to be closer to the how's and why's of actual implementation. However, many of the findings point to the need to make explicit decisions at the managerial level. Perhaps not so surprisingly, the project team found that from a teacher and student perspective, ambiguity is the most difficult mode to be in. Even in experimental design phases, the explorative nature, and a clearer path of what comes next need to be communicated. In a large organization, such as a university, with several campuses and many educational disciplines, such strategic decisions and communications may be more difficult to implement and live by.

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