Towards digital campus – improving usability of learning environments

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Abstract

Purpose: Digital learning environments provide new possibilities for organizing education. Additionally, these developments are transforming the existing and future learning environments. This research is based on a national project called Learning Landscape Retrofitting in Finland. The project develops physical-digital learning landscapes for campuses.

Design/methodology/approach: The approach is qualitative, more specifically descriptive and explorative. The approach was chosen to identify the functional and structural layers of retrofitted, digitally enriched learning environments. Three case studies are conducted in different universities. The first case study investigates the maturity level of the digital learning environments of existing buildings. The second case study introduces a multi-location classroom in two different campuses. The third case study presents a learning environment, which is enriched by using different kind of smart tools which gather data for different purposes about the use of the learning environment. The chosen cases had similar intentions to use digitalization to update the existing spaces according to new ways of learning and teaching. The emphasis in each case was in the increase of collaboration and widening diversity in the campus environment. The data used in the analysis was comprised of the documentation of project plans for the retrofitting and other written material.

Findings: Cross-case analysis indicates that both the digital and the physical architecture can be understood as layers for different functions and different stakeholders. Such structure provides a framework for developing usable digital learning environments.

Practical implications: The outcome of the research is a checklist for usable digital learning environments, which points out the topics to be co-created among different stakeholders in developing the digital campus.

Originality/value: The research provides an evidence-based overview of usability of digital learning environments emphasizing especially the retrofitting challenges in the process of developing both physical and digital usability simultaneously.

Keywords: learning landscape, digital, physical, usability, campus

1. Introduction

The Learning Landscape Retrofitting –project in Finland aims to study and develop digital and physically embedded learning landscape solutions that meet the needs of the changing educational climate in the 21st Century. The goal of this paper is to develop a framework for retrofitting physical learning environments enriched with technology. The research question of the paper is: How to structure the embedded physical and digital learning environments in order to design, use and maintain them?

University learning environments have traditionally included lecture halls, auditoriums, seminar rooms and a variety of laboratory and other specialized teaching facilities (Sandström and Nevgi, 2017). Currently, the new space typologies are flourishing and concepts such as informal and formal learning environment, hubs and innovation arenas are more common in campus development. There is evidence that versatile, flexible spaces for different teaching and learning needs enhance interaction and sense of community. Additionally it is evident that comfort factors are important for diverse users in the university (e.g. Pulkkinen & Tuunila, 2016; Rytkönen et al., 2015). Yet, the design, use and maintenance of digitally enriched learning environments have not been investigated in a holistic way. Information and communication technology design requires spatial solutions, which have not yet been systematically collected to manuals or guidance. Attention needs to be paid to the adaptability and usability of digitally enriched learning environments, learning landscapes and campuses (Alexander et al., 2013).

The paper begins with a background on the learning landscape definitions. It touches on the perspectives that are related to developing the framework. The developed framework is tested by examining three different kind of retrofitted learning environments. The conclusions propose the future directions for the development of the framework

2. Physical and digital landscape

2.1 Learning landscape

The learning environment can be seen as a physical, digital and social entity (Nenonen et al. 2015). Developing campus requires both digital and physical infrastructure for the social entity to take place (Rytkönen, 2016). Even though the case studies in this paper are based on classrooms or learning arenas, we also wish to discuss learning landscapes more generally. The concept of Learning Landscapes has emerged as a way of thinking holistically about the refurbishment and rebuilding of universities (Harrison and Hutton, 2014). While there is no agreement or simple definition as to the precise meaning of the term 'learning landscape', the use of this metaphor allows for a level of multi- dimensional thinking about the construction of universities which has been missing from the debate about the future of higher education (Neary et al., 2009).

According to Neary at al. (2009), a key issue for Learning Landscapes is the relationship between design and pedagogy. While it is logical to suppose that teaching and learning should drive design (Jamieson, 2003), in practice it has been the case that design and pedagogy appear to have been disconnected (Barnett and Temple 2006), with design imperatives coming before any specific requirements for teaching and learning. Biggs (2001) seeks to develop the notion of 'deep' and 'surface' learning through the concept of constructive alignment, by which he means getting all of the curriculum components arranged in ways that support and enhance the learning process. Biggs uses the meteorological metaphor of 'climate' to describe the importance of creating the right atmosphere in the classroom and at the institutional level for effective pedagogical practices, but again there is no sense of the importance of space in his writings (2001).

A digital learning landscape includes digital technology that has become a component of virtually all teaching and learning practices. Learning ties together environments, tools, learners, content and instructor and one can even talk about ecosystem in physical and digital platforms (Brown et al., 2015). The digitalized environments transform the requirements for the learning environments, which also necessitates changes in pedagogy. Continuous development of tools, including robot teaching assistance for instance, require an enabling infrastructure to fully harness the benefits both by teachers and the students. The new concepts are flourishing also in the context of digital learning environments, e.g. flipped classroom, blended learning (e.g. Harrison and Hutton, 2014; Sandström and Nevgi, 2017). These concepts have already integrated technology as part of the learning environment.

2.2 Functional layers

Digitalization is the integration of digital technologies into everyday life by the digitization of everything that can be digitized (“Digitalization”, 2019). The literal meaning of digitalization gives an apparent idea of development and of a technology-dependent world. What is coming to smart campuses, the emphasis remains on digital technology as the key element. So far it has not yet connected the wider objectives of an academic institution (Vasileva et al., 2018).

Digitalization transforms our behavior and there are four functional perspectives, which are often used in formulating the digitalization strategy for an organization (Viaene, 2017). In transforming the organization by digitization one can identify how digital solutions can:

1. replace something
2. support something
3. enlarge something
4. transform something even radically

These four functions for digital solutions help us to identify the processes and behaviors but they also set some requirements for the learning landscape. These functions can be seen as layers of a social space; as actions and functions.

2.3 Structural layers

Brand (1994) provides a description about layers in a built environment. He introduced the concept of "shearing layers of change"- that different parts of buildings age at different rates, causing buildings to constantly change and evolve. There are six "S"s: Site, which is eternal; Structure, which can last hundreds of years; Skin, perhaps 20 (although brick is pretty long-lasting); Services, electrical and mechanical, 7 to 15 years; Space plan - the interior layout in commercial space can be as little as 3 years; and Stuff, meaning something we bring in, "things that twitch around monthly." Blakstad (2001) has added to the model a seventh “S” which is Soul. The corporate real estate and facilities management industry is also implementing new technologies, for example by using IoT (Internet of Things) -enabled building management systems to make building performance more efficient and also by using sensor-generated data to enhance building’s user experience (Kejriwal and Mahajan, 2016). This is one of the first examples of integrating the structures of physical and digital environments from a building/construction perspective. The concept ‘cognitive building’ indicates how technology layers have increased as a consequence of the development.

Similar layers have been used both in commercial and academic literature while describing information and communication technology architectures. For example, Iivari et al. (2016) capture digital layers by describing them from a perspective of IoT ecosystem perspective. Similarly, to six “S” model’s “Site” and “Structure”, they describe infrastructure and technology such as computer systems and networks. Those are followed by “Data” level that needs to be collected, organized, secured and distributed. The platform is a concept which is connected to data. Corresponding to “Stuff” layer is the layer including equipment and tools, service and software application. This layer can be considered as the most agile and closer to user. The determinant for both physical and digital layers is user and user experience via accessibility to the service interface. Table 1 represents these structural layers from both physical and digital perspectives to form a learning landscape.

Table 1: Physical and digital layers to structure a learning landscape (Brand, 1994; Blakstad 2001; Iivari et al., 2016)

Physical layers	***Digital layers***
Soul – User Experience	
Service interface – Accessibility	
Stuff (e.g. furniture)	*Applications and services* *Equipment and tools*
Space	*Platforms and data*
Services (electrical and mechanical)	*Systems* *Building technology - sensors*
Skin and surfaces	
Structure	*Infrastructure*
Site	

3. Case studies

To understand this contemporary phenomena of digitally enriched learning environment and to identify the functional and structural layers of it, the descriptive and explorative case study approach was chosen (Yin, 2009). The chosen cases had similar objectives of using digitalization to update the existing spaces according to new ways of learning and teaching. The transformation of spaces were done due to the need to increase collaboration and also diversity the current campus environment, meaning introduce new types of spaces in campuses.

The data that was used in the analysis consisted of documentation of project plans for the retrofitting and other written material. Additionally, researchers were reflecting their own participatory experiences while each case had been developed as a part of larger research projects: Future Learning Environments (Case 1, 2012-2015), DigiCampus (Case 2, 2018 -2020) and Digital Real Estate Services (Case 3, 2016-2018). Each case took place in different universities in Finland. The first case study also includes reports about the follow-up of the case. The documentation of the two other cases are based on project plans. A summary of the cases is presented in Table 2.

Table 2: A summary of the cases

	Case 1	***Case 2***	***Case 3***
Disicpline in the University	*Faculty of Behavioral Sciences*	*Non-faculty initiative*	*Non-faculty initiative*
Location	*Capital Area, Finland*	*Eastern Finland*	*Northern Finland*
Retrofit year	*2014*	*2018*	*2016*
Old space type	*Library*	*Classroom*	*Library*
New space	*Living lab*	*Multi-location classroom*	*Innovation arena*

Goal of retrofit	*New ways of teaching and learning*	*Multi-location learning and campus connectivity*	*Informal learning and working area with smart elements for facilities services*

The case studies are:
1. retrofitted a library to an integrated learning environment
2. retrofitted classrooms in two campuses to a multi-location classroom connected via digital tools
3. retrofitted a library to an innovation arena and co-working place

Next, the cases are described in more detail.

Case 1
Minerva Plaza (MP) was originally designed and transformed for the use of the Faculty of Behavioral Sciences and its goal was to create integrated learning environments for the future. A reading hall of a library was transformed into a learning environment where the faculty could hold lectures and tutorials. MP includes a variety of spaces and services, contact teaching and digital tools, as well as Internet and mobile-based working and learning platforms dovetailing together. Minerva is designed to promote and engage learning along the pedagogy of embedded learning (ELE). ELE Living Lab is designed to trigger and innovate new socio-digital knowledge practices that are in constant dialogue with current pedagogical solutions. The basic idea behind the activities on Minerva Plaza is to create new technology-mediated, research-based pedagogical scripts and knowledge practices to improve and update especially education at universities. Digital technology is intended mainly to foster communication and knowledge management of the group. At the same time, the use of own devices (BYOD) is encouraged to enable the use of individual digital tools.

Based on our evaluation, the new space has worked well as a technology-rich learning environment and so far answered to the needs of the 21st-century students and their teachers. The feedback of the users has been mainly positive. One of the strengths of Minerva Plaza is its adaptability. The use of technology also evolves in everyday practice and provides new meaning to learning practices. (Lonka et al., 2015; Ruismäki et al., 2015)

Case 2
A Multi-location ClassRoom (MLCR) was created during 2018, combining two physical classrooms into one technical entity in a manner that enables as genuine a feeling of remote attendance as possible. MLCR is a unique new learning environment. It includes two identical classrooms in different campuses, which can be connected by video and voice through a computer application. The most significant difference to more traditional video meeting facilities is in the creation of a realistic space experience by a full wall-size screen. This requires advanced technology as well as similarity in interior design for the two classrooms. The significance of acoustics is also high. The goal of each digital and physical solution is to create a genuine experience for all participants in both campuses. In designing the sound environment, the aim has been to achieve high sound quality without any kind of rotation effect. The full wall-size screen also includes the required projection capabilities. The participants can share the content of their computer or any other digital device at predetermined locations. The same technology can be found in both of the locations, but the control is always at the side where the session administrator is. The technology is designed to be easy to use and to work as automatically as possible without the presence of technical support.

Case 3
The third case is an innovation arena, which is available for working and arranging events, the arena was called TellUs. The space was refurbished from an old library area in 2016. It is about 400 square meters of pure entrepreneurial spirit. The space includes working space, meeting rooms and nice couches to hang out and meet people. One of the actors in the space is a so called Business Kitchen which acts as an entrepreneurship hub – a community and co-working space to boost action and discover new opportunities in business and in life. It is a meeting place and a learning environment for the

curious and entrepreneurially-minded. This informal learning and working area has been a test bed for development of smart facilities services. A comprehensive wireless sensor system and an intelligent lighting system were installed in the TellUs pilot environment in 2017 for development of new real estate services. Smart virtual reality (VR) glasses are combined with Internet of Things (IoT) data and lighting that can be controlled with the VR glasses. One can also use video streams in the VR glasses. There is also an automatic wireless device positioning system in the space. Additionally, there are light beacons to determine the user's location. In order to make the smart solutions more real, a 3D model has been made of TellUs, which has helped in placing the smart lights to the correct places. Some of the sensors are also connected to a 5G network.

4. Results

4.1 Functional layers of retrofitting in cases

The analysis indicated that different drivers of the retrofitting address different priorities in retrofitting plans. The functional layers included replacing, supporting and enlarging functions – none of the cases included functions which totally transformed the activities as described by Viaene (2017). Table 3 presents an analysis of the cases with Viaene's (2017) classifications of digitalization activities as lenses.

Table 3: Functional layers

	Case 1	***Case 2***	***Case 3***
Replace	*Replacing paper study material to digital material*	*Replacing paper study material to digital material*	-
Support	*Supporting engaging pedagogical scripts instead of teacher led passive lecturing*	*Supporting collaboration between two campuses instead of working in silos in different campus locations*	*Supporting university-industry collaboration instead of keeping industry separate from campus community*
Enlarge	*Enlarging interaction by providing tools for communication during the learning activities*	*Enlarging connectivity between two campuses*	*Enlarging the informal community building, new activities and collaboration possibilities for university-industry connections*
Transform	-	-	-

As introduced earlier in the paper, the new types of learning environments aim at enhancing interaction and collaboration, thus, supporting active and deep learning methods and approaches. From the table 3 above, we can see that digitalization activities in all three cases aimed at improving on various depth collaboration and communication possibilities.

4.2 Structural layers of retrofitting in cases

The analysis identified the changes that appeared both in physical and digital environment and Table 4 presents these changes based on the previously presented framework of layers. All analysed cases aimed for improved user experience through easiness of access, usage and comfort. It related both to physical and digital solutions in space retrofitting. In all analyzed cases, main user groups included university staff and students, while Case 3 was also open to business partners. In addition, Case 1 had a more defined user-group at the beginning but now the space is also used by other faculties of the university and also by stakeholders outside the university. Including multiple stakeholder groups might set different requirements for IT infrastructure and Systems, thus, should be defined early enough so changes would not require too much investment.

Table 4: Structural layers

Physical Layers		***Digital layers***	
Soul	Easy to access, comfortable	**User experience**	Easy to access and easy to use
Stuff	Support person, BYOD	**Applications, equipment**	Applications for easy connectivity, Wireless devices, possibility for BYOD, microphones, screens, cameras
Space	Adjustable, flexible and movable furniture, storage space for equipment		
Services	Sufficient number of electric sockets for users around the space	**Platforms & data**	Open data in standardized model to develop spaces and services based on it. Virtual model of space/digital twin
Skin	Electrical wiring, lighting solutions	**Systems**	Routers for wireless connections, data management systems for saved, shared and co-created content; space reservation system, sensors as data grids, building management systems (in case 2 and 3)
Structure	Height of the room, acoustics, location of windows	**Infrastructure**	Computer and network hardware (requires high investment) Network be accessible for outside users (as in Case 3), high speed internet connectivity (in Case 2 of virtual classroom) Sensors as data grids (in some cases) BIM model
Site	Not changing physically but digital connectivity decreased the physical boundaries		

Next, user experience was supported by the service interface layer, which differed in all three cases. Cases 1 and 3 had a digital support person present or available on location whereas Case 2 emphasized that the connectivity system between two locations is so easy to use that no extra support is needed. On the most flexible – Stuff and Applications – layer, Bring Your Own Device (BYOD) policy had the biggest effect from both physical and digital environments. Also, from digital side various movable and flexible tools such as microphones, screens, cameras needed to be purchased and installment as well as outers for wireless connection were essential to make the connectivity and usage of tools easy.

Next, in physical side "Space" layer, each case emphasized the need for adjustable, flexible and movable furniture in order to provide possibilities to change them according to the needs of different situations and users. The flexibility in digital equipment was based on the use of own devices, especially in Case 1. Both Case 2 and 3 had a strong emphasis for different kinds of digital devices and equipment – some of them wireless. However, this brings challenges in storing the equipment so that it is easily available when needed.

In services and platform and data layer, the assumption in each case was that students are able to bring their own device with them. Thus, the number of electrical plugs was increased in each of the places. From the digital perspective, to enable further service and space development, the data needed to be opened and in a standardized model. Moreover, for fast change implementation and better planning, virtual model of spaces can be implemented. In Case 3, a virtual model of space helped to identify lighting solutions ensuring that sensors integrated in the lighting are powerful enough to also serve as data grid. Acoustic environment turned out to be important especially in Case 1 and 2. In Case 1 the physical conditions, e.g. the height of the room, was a challenge for collaborative learning environments, as the communication needed to be done by using a microphone. In Case 2 the acoustic planning was important to ensure the quality of voice between two locations. The demands for lighting solutions were also defined based on the use of digital tools and equipment. In Case 1, the direct sunlight from the windows forced the developers to create new structures for the screen in order to make it visible also in sunny and bright conditions. The light and use of cameras is also an issue to be taken into account in creation of two similar kind of classrooms.

In terms of data architecture, Case 3 had a plan in their project to design the data structure so that the space and even services can be developed based on it. In Case 1 and 2 the context of the activities and the data management systems included the shared, co-created and saved content within the processes. The building management systems were not taken into active use except in Case 3, where the indoor environment data was one topic of interest.

The classrooms were originally designed for different purposes. Transformation of open silent area to interactive learning environment (Case 1) was challenging, especially in terms of room height. The transformation was also an exercise of showcasing future school classroom: however, the rooms were without the windows to direct natural light. Additionally, the safety regulations e.g. with the location of entrances was not fulfilled in the proper way. The digital infrastructure was based on university networks while the users were mostly in-house users. However, in Case 3 the infrastructure, including hardware elements, was a challenge as none of the stakeholders was willing to invest in it. The role of the ecosystem actors in such an environment is part of retrofitting: the investments in physical and digital environments need to be clarified, as well as the roles and responsibilities in terms of using and maintaining the existing physical and digital infrastructure.

4.3 Summary of the results

The outcomes of these case studies were analyzed by using the functional and structural layers presented in Table 1, which shed light to the collection of actors who need to be active in the design, use and maintenance of digitally enriched learning landscapes. Designers need to pay extra attention to the requirements of digitally enriched functions in terms of interior design, comfort factors and indoor environment. Physical and digital access and ease of use have an important role in creating a positive user experience. Data and platforms provide new insights on how to design, use and maintain the space and how the data usage plans of different stakeholders need to be designed in an aligned manner. VR models can be used by designers, users and facilities service providers as an important source of achieving the desired user experiences. In retrofitting cases it is essential to identify the potential hindrances that the physical infrastructure constructed before digitalization may cause for creating the new digital infrastructure. It was noted that the digital strategies of universities cannot be fully carried out without changes in the physical environments. It is essential to identify if changes are needed in the heavy or light retrofitting layers.

5. Conclusions

The functions are important in design both physical and digital learning environments. The structural layers are possible, important and interesting to identify. They can be seen as integrated system. The planning of physical elements is not only based on user needs, but also depending on the needs and requirements of the digital tools, equipment and services. The building automation systems and data systems can be integrated in a way that data sources serve multiple purposes before, during and after retrofitting. The infrastructure is a fixed entity and also a matter of dividing different responsibilities in terms of investments among the stakeholders.

The present study is a first step towards a checklist on how to design, use and maintain digitally enriched learning environments. The headings of the usability checklist are proposed in the following way:

1. Experience-driven issues: the shared vision of the desired user experience

2. Access and services: different ways to support the ease of use of digital and physical features of the space

3. Light digital and physical solutions and the points of connection: flexibility, adaptability and movable solutions both in digital and physical stuff, as well as in indoor environment fine-tuned with human and digital requirements

4. Data and its requirements for the physical place and digital solutions: potential uses of data for ongoing development and in identifying the points of connection

5. Heavy systems and structures and the point of connection: requirements for the digital and physical infrastructure for supporting the shared vision.

The study is based on small-scale retrofitting cases and this is a clear limitation of the study. However, the first steps taken indicate that there is a potential to identify new kinds of requirements for future learning environments. The clarification of roles, tasks and responsibilities of different stakeholders will be the next step in future studies in order to support the development of a learning landscape that is in balance with technology.

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