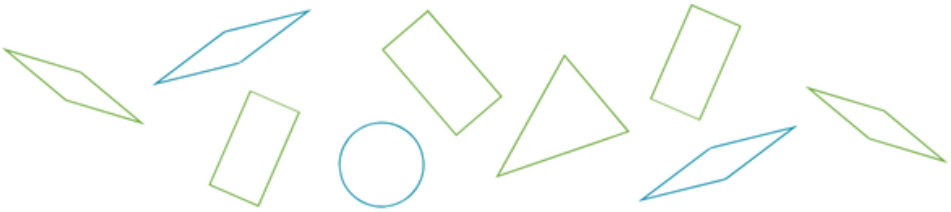

Requirements and Impacts Analysis for the sustainability of Digital Education Infrastructure

Erasmus+ KA2 C-FLEX Result 1

Main authors: Özge Okur and Yilin Huang, Delft University of Technology
Contributing authors: all partners of the C-FLEX project

www.c-flex.eu

November 2024

Co-funded by the European Union

This project has been funded with support from the European Commission under the Erasmus+ "C-FLEX" project, awarded with grant number 2021-1-IT02-KA220-HED-000032115.
This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of Contents

Chapter 1: Systematic analysis of sustainable Digital Education Technologies

Summary

This document systematically analyzes the sustainability of Digital Education Technologies (DETs), emphasizing their role in enhancing education while addressing the project's four key sustainability dimensions: environmental, social, technological, and pedagogical, while also looking at economic concerns. It provides guidelines and examples that will assist institutions in aligning their requirements with digital solutions, maximizing educational benefits while minimizing ecological impact and promoting equity.

1.1 Definition of Digital Education Technologies (DETs)

While the definition of **Digital Education Technologies (DETs)** has shifted over the past three decades since its introduction to universities, they all describe digital technology's role in enhancing the effectiveness and efficiency of teaching and learning processes. We define DETs as any digital device or software that improves the efficiency, learning outcomes, ease of use, or accessibility of the education system.

1.2 Sustainability Dimensions for DETs

Sustainability is a subject that has gained increasing attention in recent decades due to its importance in promoting a healthy environment and equitable society. While Brundtland broadly defined the concept as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" in 1987, sustainability remains a relatively open concept with many context-specific interpretations. A dominant description of sustainability by Purvis et al. (2019) has three interrelated dimensions: environmental, social, and economic. Sustainable development needs to consider all three dimensions simultaneously: environmental degradation can negatively impact social and economic well-being, while social inequality and economic instability can have detrimental effects on the environment.

In the context of sustainability for DETs, additional dimensions have been proposed to provide a more complete evaluation of the topic, predominantly the technological and pedagogical dimensions. In this section, the five dimensions will be examined for their relevance to DETs through a literature review. It is important to note that while a dimension may be excluded from analysis, it may still be incorporated later in discussing research results, such as illustrating trade-offs between dimensions decision-makers encounter when selecting for DETs.

Environmental

The environmental dimension focuses on the protection and preservation of natural resources, ecosystems, and biodiversity. According to Morelli (2013), the "maintenance of natural capital" involves the management of human activities in ways that minimize negative impacts on the environment as it provides the foundation for human societies to exist and thrive. Consequently, environmental sustainability encompasses a range of issues, such as climate change, air and water pollution, and the depletion of natural resources.

While digital education technologies bring benefits to the education system, the adoption and use of these technologies also have environmental impacts that need to be considered. In the context of digitalizing education, the increased hardware (which creates electronic waste) and software (which produces carbon emissions) are the top contributors to environmental pollution (Iyer,2014; Ong et al.,2014). The production and disposal of electronic devices such as computers, smartphones, and tablets used in universities contribute to environmental degradation. The increased global demand, paired with the shortening lifespan and significant unused number of electronic devices, has made e-waste one of the fastest-growing global waste streams (Angeli et al.,2022). In 2019, 12.1 million tonnes of e-waste was generated in Europe alone (Andeobu et al.,2021).

Similarly, while DET software usage may not directly generate physical waste, the energy consumption associated with the operation of servers, data centers, and the internet are significant contributors to greenhouse gas emissions. For example, despite a more than 90% decrease in carbon emissions by hosting lectures online instead of in person (by reducing commuting), the use of videoconferencing software such as Zoom is also not energy-efficient (Roy et al.,2008). A Zoom lecture hosted in Trento, Italy, e.g., has its data routed to Germany and back when most of the participants are joining from the same city (Angeli et al.,2022).

Social

Social sustainability is the dimension that promotes social equity, equal access, privacy, autonomy, and fairness for individuals and communities (Waas et al.,2011). Chiu (2006) defines social sustainability as “maintaining or improving the well-being of people in this and future generations … [with] the aims [of] social cohesion and integrity, social stability and improvement in the quality of life.”

In the context of DETs, social sustainability aims to ensure all learners have equal opportunities for education, regardless of socioeconomic status, disabilities, or geographic location (Daniela, 2022), while preserving individual privacy (Chang, 2021). Several key themes emerged from the literature on the social sustainability of DETs: access, accessibility, and privacy. First, DETs have been demonstrated to promote access to education, particularly in underserved, marginalized, and rural populations (Lai, 2011). Since the 2000s, communication platforms like Skype and Moodle significantly increased education participation from these groups, with the most recent example stemming from the mass online education shift during the pandemic (Crick, 2021). However, DETs can also limit access by increasing digital dependency, thus gatekeeping learning and content from already marginalized groups who do not have devices or stable internet to access content and lectures (Azad, 2021).

Second, DETs, directly and indirectly, influence accessibility in education. Accessibility builds upon the concept of access by focusing on making things easier to reach, understand, or use for everyone, especially those with disabilities or other challenges (Seale, 2013). LMS, online learning, and increased digital device ownership are some factors that have positively increased accessibility in education by accommodating different learning styles, reducing inequalities (e.g. gender), and enhancing educational experiences for students with disabilities (Beyene et al., 2020; Kerras et al., 2022; Silver, 2019). While DETs have the potential to enhance accessibility, they can also exacerbate certain challenges and introduce new barriers if not implemented thoughtfully. For example, platforms with inaccessible user interfaces, navigation structures, or multimedia content may be difficult or impossible for students with certain disabilities or challenges to use effectively (UNESCO, 2024). The concept of inclusion encompasses both access (to education) and accessibility (in education) by focusing on DETs that actively involve and embrace the participation of all individuals, regardless of their backgrounds or abilities (W3C, 2016).

Third, the collection and use of sensitive data, such as user behaviour, personal information, and student performance, have been repeatedly highlighted in research as having major security and privacy concerns for DET users (Kim, 2021). Certain videoconferencing tools have been exemplified as a platform where user data can be easily exacted and shared publicly, thus jeopardizing users by posing serious privacy breaches (Kagan et al., 2020). Additionally, DETs, including artificial intelligence learning support have design limitations that have racial, cultural, and gender bias, thus contributing to social unsustainability (Santos et al., 2022).

TECHNOLOGICAL

Technological sustainability investigates what makes DETs technologically functional and long-lasting from a design and implementation perspective. There are three key components to this dimension: simplicity, openness, and ownership (Davis et al.,2010).

Simplicity refers to how easy a DET is to understand and use for the educator, learner, and other stakeholders. Intuitive interfaces, clear instructions, and simple design are critical in creating a user-friendly DET that lowers the barrier to entry for new users. Using a familiar tool increases the simplicity and ease of use because instead of viewing the DET as an administrative or logistical learning tool, it is perceived as an extension of what they are used to and the DET is more appealing to use. In addition to increasing adoption rate and integration into educational settings, simple DETs have been demonstrated to increase student learning outcomes and teachers' confidence in using the DET in the classroom (OCED,2015).

Openness refers to the DET that promotes collaboration, sharing, and joint innovation between users (Lane, 2009). The concept of openness in DETs is not new and various definitions have existed over the past 40 years, but all centre around the idea of open educational resources.

Ownership refers to the degree to which the user or education institution can exert change to the DET and can be visualized as a spectrum. At one end, the user has full ownership of the DET, typically through a one-time purchase license, and can use the product forever. On the other end, the user has minimal ownership, often having to pay a regular subscription fee to use the product, and is subject to any product changes the provider decides to implement. The latter category has been analogized as a renter-rentee relationship as companies rent out DETs to institutions who pay a monetary rent to access the product, while the users (i.e. teachers, students) pay data rent in the form of digital traces left behind through interacting with DETs. Increasing DET ownership can reduce institutions' dependency on DET providers and increase user data security.

Digitalization has led to an increasing amount of European universities, such as institutions in the Netherlands and the United Kingdom, to become less simple, less open, and less ownership (Fiebig et al.,2021). In Figure 1, a couple of trends can be observed. First, there is a general increase in digitalization across all universities, including institutions in countries like Germany and France, where total digitalization is less than 50%. Second, digitalization is largely dominated by the same selected Big Tech companies (i.e. Microsoft, Google, Amazon), indicating universities are becoming increasingly dependent on DET renters. These trends indicate a gradual erosion of ownership as Big Tech companies move towards more subscription cloud services and rent out licenses to institutions for DET access. This introduces a less open and fragile education infrastructure as universities depend on these companies for major aspects of their operations, data storage, and digital platforms. For example, if Google decides a service is no longer financially viable, it could shut the service down, impacting many universities' that are using that service.

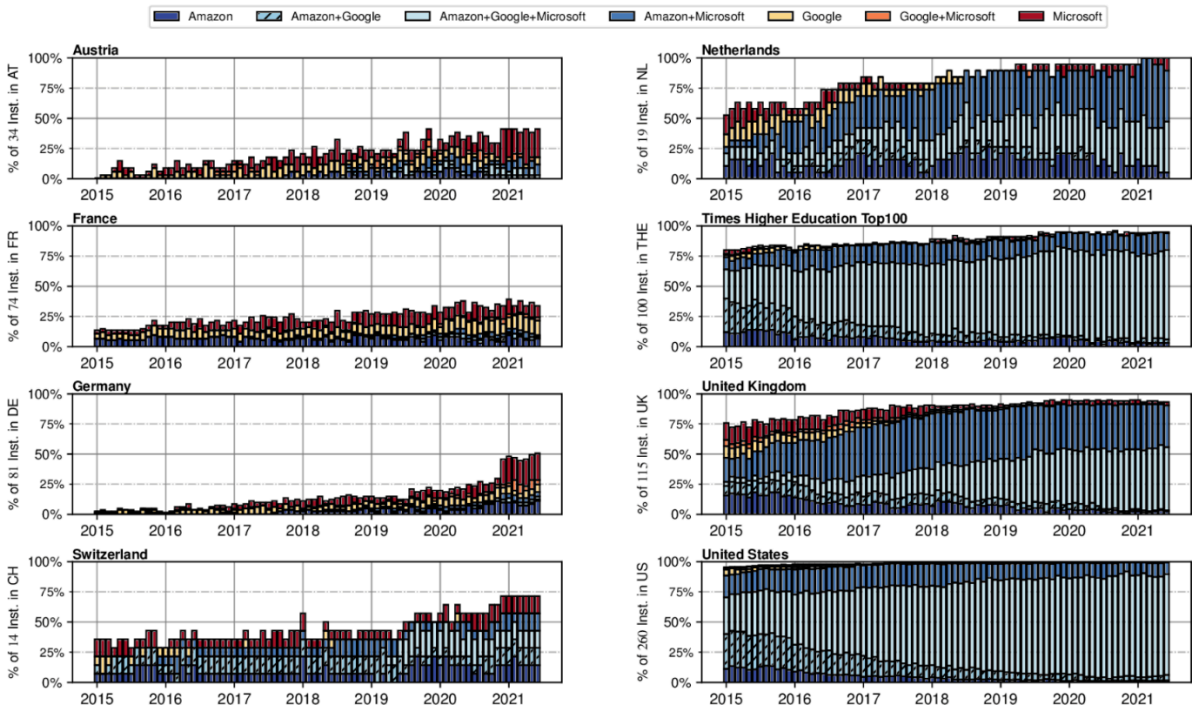

Figure 1: Technological trends in the digitalization of European universities (Fiebig et al.,2021)

PEDAGOGICAL

The pedagogical dimension examines how teaching and learning methods adapt to new DETs. Pedagogical forms have evolved concurrently to match the introduction of new DETs in order to utilize these tools to deliver better educational experiences and outcomes. Leshchenko et al. (2021) describe the assessment of DET pedagogy to involve the study of the DET's "purpose, objectives, [and] teaching strategies".

Some criteria researchers used to study DET pedagogy include the degree of students' ability to use the DET to access educational resources, interactivity on the platform (e.g. feedback, student-teacher communication), and quality of teaching approaches. These criteria help educators and technology designers better understand how effective their current pedagogy method is in relation to the DET and inform them how the technology and pedagogy may improve to achieve better learning outcomes.

The pedagogy of personalized learning through LMS has been studied in recent years as it is one of DET's most anticipated opportunities. Due to the immense burden of tailoring learning for each student based on their interests, strengths, and needs, this type of education can only be attempted by utilizing DETs. This causes a pedagogical shift away from the traditional lecture-style method to a blended learning method that employs a mixture of digital learning and teacher-led schooling (Bashamet al.,2016).

In addition to changes in how educators teach, personalized learning also places a greater responsibility on the students as they now have to self-regulate in following their individual online curricula. Dabbagh and Kitsantas (2005) highlighted that additional DETs should be implemented to provide scaffolds for self-regulated learning so that students are supported and are not lagging behind. This example demonstrates the complexity and the large number of pedagogical iterations required based on the decision to implement DETs for personalized learning.

Economic

The economic dimension has historically been a main source of disagreement in sustainability research, with a spectrum of competing thoughts on the economic dimension and how it relates to the environmental and social dimensions (Purvis et al.,2019). One end subscribes to the idea that economic growth, at least at the current rate, perpetuates inequalities and is repeatedly the cause of social and environmental unsustainability. The frequent sustainability imbalance due to the prioritization of economic growth over the other dimensions has prompted some researchers to limit the economy's role in sustainability discussions. Proponents of this side of the sustainability spectrum view economic growth as an entity that needs to be restricted rather than something where trade-offs should be made (Purvis et al.,2019).

Conversely, economic growth is believed to be a solution to sustainability issues. The advocates argue that growth is the key to meeting social and environmental goals since economic growth will have trickle-down effects, such as alleviating poverty, which will, in turn, reduce environmental degradation and improve human well-being (Castro,2004).

In the context of DETs, the economic cost and efficiency have played a significant role in how and where digital infrastructure has been built, both in Europe and globally. A prime example is the economics behind the outsourcing of digital infrastructure in universities. By externalizing services and infrastructure to third-party providers, the institutions reduce both infrastructural and human costs (Angeli et al.,2022). Additionally, as technological advances make services more effective and efficient, data centers can be relocated to countries with cheaper electricity, land, and wages at the expense of increasing the distance data travels and carbon emissions. This practice benefits these institutions and their countries, such as the Netherlands, as they outsource their pollution to other countries that host the data centers (Fiebig et al.,2021). While there are major conflicting schools of thought on the economic dimension, it has been frequently prioritized over other sustainable dimensions in the pursuit of economic growth and efficiency, thus resulting in net negative sustainability progress. Although it is clear economic dimension is important in the discussion of sustainability, it often takes the spotlight and does not allow a thorough examination of potential solutions that may have higher costs but yield positive results in other sustainability dimensions.

This study does not focus on the economic dimension in its analysis but examines the other dimensions and discusses economic cost-benefit. As it is necessary for decisions of DETs to be economically viable, research findings are discussed alongside financial and budgetary factors.

	Definition	Example
Environmental	DET protects and preserves natural resources, ecosystems, and biodiversity through the environmental impact of its hardware and software.	Less CO2 emission, recycling e-waste
Social	DET ensures all learners have equal opportunities to education, considering access and accessibility, regardless of socioeconomic status, disabilities, or geographic location, while preserving their privacy.	Language translation feature, transcriptions, video recordings
Technological	DET is long-lasting, possesses the necessary functionalities, and balances the simplicity, openness, and ownership components	Open-sourced software, easy-to-understand user interface
Pedagogical	How teaching and learning methods adapt to new DETs.	

Table 1: An overview of sustainability dimensions within the DET context with definitions and examples

1.3 Use cases from three universities

This section provides three example cases related to the sustainability of DETs in different universities in the consortium.

Case of BBB at TU Delft

At Delft University of Technology (TU Delft), BigBlueButton (BBB) was adopted as an alternative online education platform, especially during the COVID-19 pandemic. The platform was initiated by staff members from the Faculty of Technology, Policy, and Management to provide an open-source option compared to mainstream tools like Zoom or Teams. BBB offers features such as an integrated whiteboard, built-in surveys, and automatic breakout rooms, making it particularly attractive for educational purposes. However, as of early 2022, concerns arose about the future of the BBB platform after some employees announced their departure, leaving the platform vulnerable without dedicated admins. There were discussions among faculty members and IT departments to ensure its continuity and possibly expand its usage across more faculties. However, there were not sufficient financial resources to continue the BBB platform's operation since the university decided not to allocate a budget for the maintenance of BBB. This is an example of a significant effort at an HEI to maintain an open-source DET (dealing with technological dimension), which did not work due to inadequate financial resources.

Case of ICT Services at Uni Trento

In the first half of the 2010s, a major IT firm approached the University of Trento (UniTrento) with a generous proposal to provide email, calendar, and unlimited online storage services to the university's staff, students, and alumni at no cost. At the time, UniTrento managed these services in-house, but the firm's offer was too attractive to ignore. In compliance with Italian law, the university initiated an open bidding process. After evaluating several offers from other IT companies, UniTrento conducted a cost-benefit analysis and ultimately chose to outsource the services to the firm that offered them the services free of charge.

The ten years that passed since the beginning of this service, much has changed. The GDPR entered in force in the second half of the 2010s and, while there are no definitive indications of whether the company is fully compliant with GDPR. Other pieces of regulation, including the DMA, the AI Act and, in part, the DSA, are also bound to have yet-not-understood effect on those services. The company's terms of service also change. As an example, in late 2021, it proposed to make its Workspace UniTrento Alumni a paid service.

The University decided not to accept the proposed financial conditions, as the service was considered not critical. However, it's fundamental to note that, in these contractual conditions, the University will always be in a reactive position. If or when a similar situation would arise for a more critical service, the University's decision-making space is expected to be limited.

Notably, hosting university ICT services by external provider provides many benefits but also reduces significantly a university's ability to act on the sustainability of their digital infrastructure. While this case study doesn't concern a purely educational technology, many of the lessons learned from this case can be applied to education infrastructure, including the following:

When estimating costs for deploying digital infrastructure, universities should not only consider entry costs, but also exit costs. Universities should pay extra attention to correctly model the inevitable growth of exit costs over time, identifying tipping points, and preparing contingency plans.

When relying on external providers for digital education infrastructure, universities should consider that it is highly likely that, as organisations, universities may outlive their service providers, hence need longer term planning.

During the procurement phase, universities should look beyond economic concerns. The C-FLEX sustainability dimensions is a starting point for what concerns digital education infrastructure.

Case of Proctorio at TU/e

At the start of the COVID-19 pandemic in 2020, the Eindhoven University of Technology (TU/e), like all other universities in the world, faced a challenge: how to ensure academic integrity during remote examinations. The solution that was quickly chosen was a software package called Proctorio: an AI-based algorithm to automatically flag suspicious behavior during online tests, which can then be checked by a human agent. However, different than most universities in the world, TU/e took a collaborative approach, involving official representatives of staff and students in the decision-making process and developing a protocol that addressed their concerns.

The Story of Proctorio at TU/e

At TU/e, the pandemic had brought about a sudden shift to online learning. The university, determined to uphold the integrity of its exams, introduced Proctorio. TU/e invited its staff and students to join the roundtable, seeking their counsel on how to implement this new guardian of remote exams.

The representatives, with their diverse perspectives, voiced their concerns and hopes. They spoke of the importance of exams aligning with the essence of their courses, rather than just being a fortress against fraud. They looked at the main lines, the details, and the practicalities of exams. How to introduce a piece of software that would be introduced to guard the quality of the exams, rather than a watch dog for fraud. The students also shared their reluctance and asked that some of them could opt out of Proctorio's watchful eye, out of privacy concerns. The consensus was clear: Proctorio was not a pleasant companion on their academic journey, but if it must accompany them, it should be introduced as a natural necessity, guarding the quality of the exam, not as a way to monitor students and pry in their privacy. The overarching sentiment was that Proctorio should be a last resort, used only when it aligns with the course's learning goals and after careful consideration of the additional stress it imposes on students.

And so TU/e listened carefully. They crafted a protocol that balanced the need for vigilance with the well-being of their students. Proctorio became a tool used sparingly, and the students, understanding the reasons behind its presence, were more satisfied with its application. The monitoring was done in the least invading way and with respect to the students. There were possibilities for students to have a restroom break in between, and the exam software was seamlessly integrated. Students valued a testing method that resonated with the subject matter more than a mere reduction in the risk of cheating. They preferred the privacy of their own study place during exams and were hesitant to opt out of Proctorio, not wanting to limit options for others.

Contrast with UvA

Meanwhile, at the University of Amsterdam (UvA), but also at other universities in the world, the narrative was starkly different. The students there, not consulted in the same manner, felt a growing unrest. Protests erupted, calling for the banishment of Proctorio, even amidst the pandemic. They felt unheard, their concerns unaddressed, and their dissatisfaction almost put the University in an impossible situation; abolishing Proctorio, or any other vigilant software solution, would make it impossible to assess courses in Covid times. The quality of education was under pressure.

The Drawbacks of the Social Aspect

Despite the best intentions, Proctorio's blade was double-edged. It was not as inclusive as one would hope, casting undue suspicion on those with darker skin tones. Its effectiveness was also questioned, as it seemed to act more as a placebo, providing a sense of surveillance without truly discerning between unintended actions and actual deceit.

Chapter 2: Stakeholder Analysis

Introduction

In this section, the important actors in the context of DET research are analyzed. This analysis considers four key actors who are integral in DET selection and fulfill unique roles in the decision-making process, which are explained below.

Head of IT

First, Head of IT is a university actor whose main responsibilities include managing the IT team, collaborating with multidisciplinary stakeholders, and developing and implementing the university's IT strategy. They act as the bridge to translate the high-level objectives from the upper echelons of the university government into actionable initiatives for the IT team. While they may not have a deep understanding of specific DETs, they have insights into how the tool fits within the broader infrastructure to make decisions during the tendering process. The Head of IT also balances the IT budget and resources to support the university's IT needs efficiently. This can take the form of evaluating current systems for areas of improvement, greenlighting pilot DET projects of new technologies, and developing and enforcing policies to align with relevant data protection regulations such as GDPR. These actors hold significant power in directing their institutions' DET selection and digital infrastructure development while operating under the constraints of the university board.

IT tool specialist

Complementary to the Head of IT, the IT tool specialist is the second university actor who has in-depth knowledge about one or more DET. These actors support the DET selection process by providing evaluations of a tool, including its functionalities, trade-offs, and scalability from a technical perspective. Outside of researching a DET to obtain these data, these actors are often involved in pilot projects to test emerging technologies, gather user feedback, and assess the tool's effectiveness.

Service provider

Service provider is the third group of actors and is responsible for the development and implementation of DETs. Established and startup companies both fall into this category as they play a similar role in providing solutions to institutions' infrastructural needs. However, established corporations are typically involved in larger tenders given their abundance of resources while startups receive smaller contracts or work with pilot projects. These actors fill the niche in providing services for university's increasing demand to digitalize their infrastructure, especially since institutions lack the funding, manpower, and expertise to maintain in-house development teams.

Education association

Lastly, Education association is a cooperative organization of educational and research institutions that work collectively towards an open education network, usually assembled on a national level. The Netherlands' SURF and Ireland's HEAnet are two examples of this type of actor. The associated institutions share solutions to various education-related challenges, including digital infrastructure services that pertain to DET selection.

For example, HEAnet assists IT departments in how to best maintain and stay up to date with IT security services through IT policy development, risk assessment, and security awareness training. Education associations can also play a big role in assisting universities in making DET procurement by establishing tendering frameworks that universities follow to select a new tool.

Chapter 3: Participatory Analysis

Introduction

The participatory analysis consists of two parts: (1) an interview study and (2) a workshop. In the first part, we conducted interviews with key decision-makers in European universities in order to understand how sustainability is taken into account in the selection of DETs at their organizations. Interviews were chosen over other data collection methods, such as surveys as proposed in the original project plan, because of the option if interviews to more deeply follow up on the investigated topics and respondents' answers through conversations. In the second part, to engage a wider variety of stakeholder groups, we complemented the interviews with a workshop among consortium partners. The results of the interviews and the workshop are presented as follows.

3.1 Interviews

The perspectives of DET decision-makers in European universities were collected through interviews. Semi-structured interviews were used to flexibly adapt the question order and allow for the interviewee's expertise and answers to dictate the conversation direction. All interviews were conducted online since the interviewees were sampled across Europe. All interviewees had access to and were familiar with the online video-conferencing platform used, and the interviews required no physical aids or materials.

Interview Design

The interview questions were constructed based on the findings from the literature review in Part 1, using strategic interviewing theory, and grouped into five sections. The interview questions are listed in Table 2. Section Introduction & context-setting has questions for the interviewee's background and sets the context for the rest of the conversation. The Sustainability & DETs questions introduce this study's sustainability dimensions and invite the interviewees to share their current understanding of DET sustainability. The Sustainable DET dimensions sections include questions framed specifically along each of the three dimensions to deeply explore the sustainability of the DET selection process. Selecting DETs questions walk through the institutions' current DET selection process, while Challenges & struggles questions examine the roadblocks decision-makers face when incorporating sustainability into these processes. Finally, the Wrap-up & organizational change questions conclude the conversation with final recommendations and brainstorm with the interviewee on how they may increase the sustainability of their university's DET selection process.

Category	Question
Introduction	How would you describe your role/position at your institution? What are your main responsibilities?
	What criteria do you consider when selecting DET for your university?
Sustainability & DETs	For this study, sustainable digital education technology is defined as "any digital education technologies that promote or incorporate environmental, social, and technological sustainability in its design, development, use, and disposal". How would you rank the dimensions (environmental, social and technological) in terms of importance when selecting DETs for your institution? Please explain your choice.
Selecting DETs	How are the sustainability dimensions incorporated into the DET selection process?
	When was the last time you saw one of these dimensions considered in your university's DET decision-making process?
Challenges & struggles	Tell me about the hardest challenge you've faced with respect to selecting DET for sustainability.
	How did you solve the challenge?
Wrap-up & organizational change	What is the most easily achievable change to make selecting DETs more sustainable at your institution, and how would you start going towards making it happen today?
	Is there anything you wanted to mention that we didn't cover today?

Table 2: Interview questions

Interviewees

This project defines decision-makers in the formal sense and refers to key actors who participate in their institution's selection of DETs and often have the power to significantly affect the decision outcomes. Thus, while students, teachers, and university staff may have an influence on a tool's selection as end users, they are not categorized as decision-makers. People considered to be in this group typically hold titles such as Head of IT, Chief Information Officer or Vice-president for ICT. They are the target group for this study as they are responsible for coordinating their university's IT strategies and processing DET requests. Therefore, these candidates have the most context and influence over DETs and the inclusion of sustainability in their selection.

The initial candidates were sampled from the researchers' professional network, with additional candidates identified through snowballing sampling and referrals. The C-FLEX consortium and partners were also contacted and asked for candidate recommendations at their institutions. Finally, a list of candidates was compiled by searching through university department staff and was sent interview requests. This led to ten interviews with 4 Dutch, 2 Finnish, 2 Irish, 1 Italian, and 1 German decision-maker. Each interview lasted about one hour. These interviews were recorded and transcribed for data analysis (including coding). The results of the analysis are summarized in the next section.

How sustainability is taken into account in DET selection

Environmental

Decision-makers highlighted the two key environmental impacts resulting from DETs were carbon emission and e-waste, which align with the literature review. Interviewees have noticed a trend towards incorporating more environmental criteria in the selection process. An interviewee from Germany stated they see during discussions for procuring new software, actors are increasingly concerned with the environmental footprint of products. An interviewee from the Netherlands mentioned the university has implemented a pilot called Remote Labs, where students participate in laboratory activities from home and found a significant reduction in carbon emissions by removing the need to commute to campus.

For electronic wastes, most originate from laboratory equipment and old electronics (e.g. computers). However, much e-waste is disposed of not because it is unusable but because there are newer models. Therefore, users and institutions have set up recycling e-waste programs for discarded but still operational electronics to reduce e-waste. An interviewee from Finland resells used and recycled laptops to students and staff at a lower price. Interviewees from both Germany and Italy reuse older computers to run server systems.

During the selection process, universities have begun to require companies to declare how their operations impact the environment and what environmental policies they have set in place. Interviewees from Germany and Ireland indicated that they ask service providers how e-waste is handled and sometimes ask the company to provide evidence (e.g. certificate) on their process for e-waste recycling. This helps the decision-makers understand how the service providers address environmental sustainability, which can be considered in the evaluation stage.

Social

From the interview data, inclusivity and privacy were the main social issues considered by decision-makers and translated into selection criteria. One goal of people-first as described by an interviewee from the Netherlands, is incorporating "inclusive and accessible techniques for learning and teaching" to reach more students. Inclusion is a common criterion that six interviewees cited as a kickout criterion because as an interviewee explained, universities cannot choose a "new technology but exclude certain users". Accessibility pertains to a more technical aspect of inclusion, as it is more concerned if users can actually use the tool and if they can use it effectively. Student organizations at this German university have requested more tooling to be accessible to students with special requirements, such as blind students. This was translated into an accessibility and inclusion criterion when selecting a videoconferencing DET, leading to the decision-makers choosing a solution that supported screen readers that allowed users to read text on screen with a speech synthesizer or braille display.

Secondly, people-first work to preserve the privacy of their users, which in the context of digital and online technologies is a primary concern for users, given that corporations have a history of selling user data and putting their users at risk. All ten interviewees indicated privacy is a major knockout criterion, especially since GDPR is a mandatory requirement all companies must comply with. An interviewee indicated privacy is the "biggest priority in all [selection] cases" and has data protection officers to establish a strong data management system. Another interviewee also mentioned their university would "not acquire a tool" even if it has "great functionalities" if it fails to provide adequate data protection.

Technological

The three components of the technological dimension introduced previously (openness, simplicity, and ownership) were all discussed during the interviews. Openness was the least mentioned aspect out of the three categories. While some open-source DETs are prominently used in some universities in Germany, Finland and Italy, they were typically not chosen for open-source features but because of their functionality and customizability that allowed actors to solve their problems. One interviewee indicated their preference for open-source DETs", but if there is another tool that fits our needs better that is not open source, then we go for that solution." Similarly, one interviewee from Italy mentioned their university actors "do not consider too much on the openness

of the software", but if they do use open-sourced tools, it is because its functions best fit their needs.

The simplicity of a tool is an important criterion from the decision-makers' perspective because it has implications for a tool's adoption by its users. One of the reasons universities run pilot projects is to get user experience feedback because there have been situations, experienced in the Netherlands, where a tool meets all the needs and requirements on paper but in practice, it was not easy to use, and users did not like the tool. While ease of use can refer to how intuitive and simple the user interface is, it can also refer to how easy it is to set up the tool. An interviewee from Italy mentioned they chose Google Meet for its videoconferencing software because it required almost no time to set up the system as it can be accessed directly on a web browser instead of installing a separate application like Zoom. A DET's simplicity also applies to IT tool specialists in its integration with the existing digital infrastructure. An interviewee from Italy also stated they might “favour services that are easy to integrate with our existing services like Microsoft and Google" as the data can easily flow between the tools, and users do not need to create new accounts.

Lastly, DET ownership was discussed extensively, especially on in-house development versus outsourcing. As shown in Figure 1, the increased digitalization in universities has led to more outsourcing of digital infrastructure to service providers. Interviewees explained the motivation to outsource with three main reasons. The first is to reduce the cost, both the financial cost to develop and maintain the infrastructure and the human labour cost of hosting an internal development team. Second, the core function of universities is to deliver quality education and not tool development. As the interviewees from the Netherlands and Ireland highlighted, the IT tool specialists lack the expertise to compete with service providers in providing the best tool support, while additional investment into DET development is taken out of potential investment into creating better education content, hiring professors, and building facilities. Third, the DET market has grown sufficiently large that there exists a product in the market that meets the needs of the university. Therefore, the university saves time by outsourcing rather than developing a more expensive but inferior product.

Many outsourced software takes the form of obtaining Software as a Service (SaaS) licenses on a subscription payment basis. For example, universities would pay for a certain number of users for one year and its students and staff can access the tool. Universities in the Netherlands and Ireland mentioned they prefer SaaS products as they are easier to maintain and relatively easy to tender for. However, there are also risks associated with these licenses because institutions have less ownership. This means they are subject to service provider's price increases, changes to privacy agreements, and updates to the tool's functionalities.

Ranking of Sustainability Dimensions

In the interviews, decision-makers were asked to rank the three sustainability dimensions - social, technological, and environmental - in order of importance in DET selection. The social and technological dimensions were consistently ranked as the most important dimension (8/10) because "there are knockout criteria from the technological and social perspectives.". The results indicate how a tool's functionality, privacy, and data security were the top three criteria (and concerns) for decision-makers, and if these were not met sufficiently, the DET is disqualified for further consideration.

Moreover, the social dimension outranked the technological dimension, with seven instances ranked as the top priority versus three instances, respectively, with zero instances for the environmental dimension. One interviewee from Germany explains this by citing that the privacy concern under social sustainability has "many rules and regulations such as GDPR" that strictly define the types of DETs decision-makers can consider. The functionality kickout criteria are usually set by the decision-makers themselves so there is more leeway in what tools can be chosen. On the other hand, as an interviewee from the Netherlands observed, "there are no knockout criteria" for the environmental dimension. The main reason for the absence of environmental knockout criteria is that it is difficult to measure environmental impacts accurately, or the data is entirely missing either because service providers do not provide or have the data or universities are not tracking the environmental impacts (e.g. CO2 emissions) internally. While some recent initiatives in universities, such as TU Delft, have begun to measure carbon emissions at the university, these are not able to be conducted on the scale of individual DETs.

3.2 Participatory Analysis - Workshop

To complement the interview results, we organized a workshop with the C-Flex project consortium members to gather other perspectives on the challenges in sustainable DETs. Note that the interviews conducted were with university staff such as Head of IT, Chief Information Officer and Vice-president for ICT. The (five) participants of the workshop, providing complementary perspectives, consist of three university faculty members and two senior education advisors. The process of the workshop was organized in four steps listed as follows.

1. The challenges identified from the interview results (see Section 3.1) were presented to and discussed with the participants.
2. Round table discussion about whether the participants have observed these challenges at their current and past institutions or the institutions they worked for.
3. Round table discussion about what other challenges of sustainable DETs the participants experienced.
4. Round table discussion about the operational steps to address or overcome the challenges.

The challenges identified in section 3.1 were recognized by the participants at their own institutions. In addition to these challenges, three additional major challenges were identified and discussed during the workshop.

1. **Content (including data) ownership and protection:** Who are the owners of the content and data created by the instructors and students using the DETs? Who are responsible for content (and data) protection? There is limited, and sometimes incorrect, knowledge of content and data sovereignty. Many HEIs (staff) are not educated about the implicates of, e.g., not owning and managing their own infrastructures and services. Within the EU, many HEIs (staff) get lost in the GDPR process – the regulations are sometimes very hard to apply. A DPO (Data Protection Officer) may be in place, but people don't know what are within their responsibilities, when to speak to them, or what constitutes "personal data".
2. **Legal liability:** Managing DETs is complex, and any HEIs (staff) have the perception that if they manage the DET infrastructures or services themselves, they would need to face the legal consequences of failure. This perception contributes to outsourcing DETs to the EdTech industry, which has a global market size of around USD150 billion in 2023.
3. **Technology fatigue:** The fast pace of digitalization has had a strong social impact. Social changes are much slower than the technological changes. Not all people can adapt to the changes of knowledge, work styles, learning tools and services, etc. Some people feel overwhelmed and tired of the changes and concerns come with them, e.g., privacy and security issues.

3.3 Challenges identified in sustainable DET selection

Based on the interview and workshop results, we identified eight major challenges universities face while selecting sustainable DET. They are grouped into three categories: Resources, Selection Processes, Selection Criteria & Decision Power, which are explained in this section.

Category A: Resources

For the available resources for DET selection, three main challenges are common to the interviewees: limited financial resources for DETs, limited IT human resources, and dependency on in-house DET tool expertise.

Limited Financial Resources for DETs

The most common challenge, discussed by all ten interviewees, was limited financial resources available for choosing a preferred DET option. The economic consideration (mainly cost weighting) is, as a matter of fact, a significant factor for decision-makers, often taking up to forty percent in criteria weighting. This significantly reduces the impact of sustainability dimensions influencing the evaluation of DETs. It was not uncommon that although decision-makers would prefer to procure a DET that meets most of their requirements, they were forced to choose another alternative due to the immense cost, e.g., for a notably more expensive data security license. Economic factors often overshadow other considerations.

Limited IT Human Resources

Resources need to be considered beyond just DET procurement but also for its maintenance and system upkeep, which require trained IT experts and a well-staffed team. Because a HEI's core function is not DET development but education and research, there has been (understandably) ``a handful of'' IT specialists and in-house developers to create minimal viable products and adjustments to the IT infrastructure. The IT human resources are not sufficient to properly support a full team to fulfill the fast-growing demand for new DETs, including the expertise and support needed after the procurement. This is also a reason for the outsourcing trend in HEIs since DET service providers can fill the demands.

Dependency on In-house DET Tool Expertise

The type of in-house IT expertise for tool support also plays a role in DET selection. New DETs would often solely rely on external service providers, who lack the organisational context and priority to provide tailored support and can take longer to respond, compared to internal IT experts. The latter can provide the needed support much faster, but it takes time and experience to gain expertise in new DET tools. This is why, sometimes decision-makers choose older and more mature DET tools, which are typically less sustainable than their newer counterparts and better embody the recent trends of people-first, privacy, and data security values.

Category B: Selection Processes

Two challenges are prominent regarding the DET selection processes: the long selection processes, and the fact that the processes require multi-disciplinary collaboration.

Long DET Selection Processes

There are often long formal tender processes for DET selections, which could take years. This makes the procurement of different tools or technologies complex to manage. The lengthy time span comes from various selection stages, where typically research, exploration, and experimentation are longer than other stages. Due to the length and complexity of the process, decision-makers often ``want to ensure that the tool can serve us for a long time''. Long DET contracts provide stability, but they also prevent HEIs from tendering for new products, which may be better and more sustainable.

DET Selection requires Multi-disciplinary Collaboration

DET selection processes often require multi-disciplinary collaboration across different departments and actor groups. This is necessary and beneficial, but at the same time complex to manage. Many actors are involved in the DET selection (and maintenance), and they can have different perspectives and even conflicts on issues such as the selection criteria, how weights are distributed, and what tools to eliminate. Sometimes, actors may (consciously or unconsciously) approach a selection process fixated on a DET they plan on selecting for, even before the research stage has started. Such biases negatively affect a selection process and hinder a fair decision.

Category C: Selection Criteria and Decisional Power

Three main challenges are grouped into this category: decision-makers in HEIs have limited information about the environmental sustainability of DETs; it is hard to balance DET selection criteria, particularly those across different sustainability dimensions; and HEIs increasingly have strong technological dependency on DET service providers due to decreased DET ownership.

Limited Information about the Environmental Sustainability of DETs

The rapid pace of digitization leads to a scramble for solutions prioritizing immediate needs such as functionality and remote access over long-term sustainability considerations, including environmental sustainability. No universities we interviewed or their service providers have or gathered data about the environmental impact of DETs, presumably because this is difficult to measure. Thus, environmental metrics are often excluded from selection criteria due to the lack of information. This gap makes switching to more sustainable DET options challenging. There is a shortage of expertise, instruments, and resources within institutions to evaluate and implement sustainable DETs effectively.

Hard to Balance DET Selection Criteria

It is challenging to balance different DET selection criteria, particularly those across different sustainability dimensions. For example, privacy (and data security) in the social sustainability dimension is currently widely considered -- nine interviewees cited GDPR compliance as the top DET selection (and knockout) criterion. This reduced the DET options such that often a little or sometimes only one option in the market remains to a university even if the remaining option(s) may not be great functionally or not meet other criteria. Moreover, cost and functionality are strong determinants, as mentioned earlier. They give less attention to other criteria, e.g., accessibility (and inclusion) in the social sustainability dimension and the environmental impact of hardware and software, which are less or much less considered during decisions.

Strong Technological Dependency on DET Service Providers due to Decreased DET Ownership

The trend towards a renter-rentee relationship, i.e., HEIs increasingly outsource digital infrastructures and services, creates HEIs' strong dependency on DET providers. There are clear benefits to outsourcing, which, however, also has associated risks. For example, when the service providers change DET functionalities or service conditions for support or prices later on, HEIs are limited in the actions they can take and often are subject to companies' decisions. Vendor lock-ins weaken HEIs' autonomy and decision-making power in the DET selection process. Vendor lock-ins often occur when HEIs choose a service provider that is an established corporation that offers a bundle of DETs, that interoperate well together. Such an arrangement makes HEIs hard to choose alternative DETs from other service providers in the future because of the high switching cost.

3.4 Trade-offs between sustainability dimensions

This section includes the trade-offs between sustainability dimensions identified in the analysis. Table 3 demonstrates and explains the main trade-offs.

	Sustainability dimensions involved
Trade-off 1	Functionality (Technological) vs. Privacy (Social) This is exemplified by many USA companies' DETs that interviewees have highlighted often have great functionality but poor data security and do not comply with GDPR.
Trade-off 2	Outsourcing (Ownership, Technological) vs. Autonomy (Social) The adoption of DETs from service providers may diminish the autonomy and decision-making authority of institutions, potentially leading to reduced control over pedagogical approaches, data ownership, or strategic decisions.
Trade-off 3	Insourcing (Ownership, Technological) vs. Cost (Economic) The DET market has grown sufficiently large that there exists a product in the market that meets the needs of the university. Therefore, the university saves time by outsourcing rather than developing a more expensive but inferior product.

Table 3: Trade-off analysis of sustainability dimensions

Chapter 4: Conclusions & Recommendations

Introduction

Based on these findings from this Result, several conclusions are drawn, and recommendations are made to universities.

Recommendations

- Although universities aim to prioritize sustainability when selecting Digital Educational Technologies (DETs), economic factors often dominate the decision-making process. This can limit how much other sustainability dimensions are considered.

- Our results indicate that the sustainability of DETs is a multifaceted issue, requiring Higher Education Institutions (HEIs) to adopt a holistic approach when integrating these technologies into their systems. Balancing the different dimensions of sustainability remains challenging. For instance, while privacy is widely considered within the social sustainability dimension, other criteria, such as accessibility, inclusion, and the environmental impact of hardware and software receive much less attention in the decision-making process.

- The results highlight the need for greater consideration of environmental aspects of sustainability, which are frequently given lower priority by decision-makers in HEIs due to a lack of high-quality data on the environmental impact of DETs. Collecting good quality environmental impact data can support the inclusion of the environmental dimension in DET selection criteria.

- We also identified several other challenges while selecting sustainable DETs, including limited resources and lengthy tender processes. Identifying these challenges opens opportunities for actors to collaborate and implement potential solutions to enhance sustainability in DET selection. The long and complex processes often motivate decision-makers to sign long (and often expensive) contracts so that they do not need to frequently repeat the selection process. The long process and long contracts reinforce the high costs and limit a university's ability to try new DETs and remove outdated DETs from its infrastructure. To that regard, an alternative shorter process could allow for a faster selection timeline, with shorter contracts that allow decision-makers to essentially experiment with DETs with no long-term obligation.

By addressing the environmental, social, and technological dimensions, HEIs can better align their digital strategies with broader sustainability goals. Future research should continue to explore these dimensions, particularly the economic aspects and their intersection with other factors, to provide a more comprehensive framework for sustainable digital education.

References

Angeli, L., Okur, O., Corradini, C., Stolin, M., Huang, Y., Brazier, F., Marchese, M. (2022). Conceptualising Resources-aware Higher Education Digital Infrastructure through Self-hosting: a Multi-disciplinary View. Eighth Workshop on Computing within Limits.

Andeobu, L., Wibowo, S., Grandhi, S. (2021). An assessment of e-waste generation and environmental management of selected countries in Africa, Europe and North America: A systematic review. Science of The Total Environment, 792, 148078. https://doi.org/10.1016/J.SCITOTENV.2021.148078

Azad, S.M.A.M. (2021). Edtech Start-ups In The Education Ecosystem In The Post-covid-19 Era In India. Towards Excellence. https://doi.org/10.37867/TE130482

Basilaia, G., Kvavadze, D. (2020). Transition to Online Education in Schools during a SARS-CoV-2 Coronavirus (COVID-19) Pandemic in Georgia. Pedagogical Research, 5(4). https://doi.org/10.29333/pr/7937

Bejinaru, R. (2019). Impact of Digitalization on Education in the Knowledge Economy. Management Dynamics in the Knowledge Economy, 7(3), 367–380.

Beyene, W.M., Mekonnen, A.T., Giannoumis, G.A. (2020). Inclusion, access, and accessibility of educational resources in higher education institutions: exploring the Ethiopian context. International Journal of Inclusive Education, 27(1), 18–34. https://doi.org/10.1080/13603116.2020.1817580

Bramble, W.J., Panda, S.K. (2008). Economics of Distance and Online Learning: Theory, Practice, and Research. Routledge, New York.

Brown, A. (2009). Digital technology and education: Context, pedagogy and social relations. Education and Information Technologies, 1159–1172.

Chang, B. (2021). Student privacy issues in online learning environments. Distance Education, 42(1), 55–69.

Chiu, R.L.H. (2006). Socio-cultural sustainability of housing: A conceptual exploration. Housing, Theory and Society, 21(2), 65–76. https://doi.org/10.1080/14036090410014999

Claeys-Kulik, A.-L., Jørgensen, T.E., Stöber, H. (2019). Diversity, equity and inclusion in European higher education institutions. Results from the INVITED Project. European University Association, 51p.

Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., Magni, P., Lam, S.M.S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. Journal of Applied Learning & Teaching, 3(1). https://doi.org/10.37074/JALT.2020.3.1.7

Crick, T. (2021). Covid-19 and Digital Education: A Catalyst for Change? ITNOW, 63(1), 16–17. https://doi.org/10.1093/ITNOW/BWAB005

Daniela, L. (2022). Inclusive digital education (pp. 1–11). Springer.

Davis, H.C., Carr, L.A., Hey, J.M.N., Howard, Y., Millard, D., Morris, D., White, S. (2010). Bootstrapping a culture of sharing to facilitate open educational resources. IEEE Transactions on Learning Technologies, 3(2), 96–109. https://doi.org/10.1109/TLT.2009.34

El Geneidy, S., Baumeister, S., Govigli, V.M., Orfanidou, T., Wallius, V. (2021). The carbon footprint of a knowledge organization and emission scenarios for a post-COVID-19 world. Environmental Impact Assessment Review, 91, 106645. https://doi.org/10.1016/J.EIAR.2021.106645

Evangelista, R., Guerrieri, P., Meliciani, V. (2014). The economic impact of digital technologies in Europe. Economics of Innovation and New Technology, 23(8), 802–824.

Fiebig, T., Gürses, S., Gañán, C.H., Kotkamp, E., Kuipers, F., Lindorfer, M., Prisse, M., Sari, T. (2021). Heads in the Clouds: Measuring the Implications of Universities Migrating to Public Clouds. arXiv. https://doi.org/10.48550/arxiv.2104.09462

Gallicano, T.D. (2013). An example of how to perform open coding, axial coding and selective coding. Public Relations Review. https://doi.org/10.1016/j.pubrev.2013.03.001

Haleem, A., Javaid, M., Qadri, M.A., Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable Operations and Computers, 3, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

HEAnet (2023). HEAnet is Ireland's National Education and Research Network. https://www.heanet.ie/

Herth, A., Blok, K. (2022). Quantifying universities' direct and indirect carbon emissions – the case of Delft University of Technology. International Journal of Sustainability in Higher Education, 24(9), 21–52. https://doi.org/10.1108/IJSHE-04-2022-0121/FULL/PDF

Iyer, L.S. (2014). A Study on the Attitude Towards e-Waste Collection and Safe Management in Academic Institutions in Bangalore. SSRN Electronic Journal. https://doi.org/10.2139/SSRN.2480323

Jacques, S., Ouahabi, A., Lequeu, T. (2021). Synchronous e-learning in higher education during the COVID-19 pandemic. 2021 IEEE Global Engineering Education Conference (EDUCON), 1102–1109. IEEE.

Jeronen, E. (2020). Sustainable Education. In Idowu, S., Schmidpeter, R., Capaldi, N., Zu, L., Del Baldo, M., Abreu, R. (Eds.), Sustainable Education (pp. 1–10). Springer, Cham. https://doi.org/10.1007/978-3-030-02006-4_237-1

Jung, I., Rha, I. (2000). Effectiveness and cost-effectiveness of online education: A review of the literature. Educational Technology, 40(4), 57–60.

Kagan, D., Alpert, G.F., Fire, M. (2020). Zooming Into Video Conferencing Privacy and Security Threats. IEEE Transactions on Computational Social Systems, 1–12. https://doi.org/10.1109/TCSS.2022.3231987

Kaputa, V., Loučanová, E., Tejerina-Gaite, F.A. (2022). Digital Transformation in Higher Education Institutions as a Driver of Social Oriented Innovations. In Păunescu, C., Lepik, K.-L., Spencer, N. (Eds.), Digital Transformation in Higher Education Institutions (pp. 61–85). Springer, Cham. https://doi.org/10.1007/978-3-030-84044-0_4

Kedraka, K., Kaltsidis, C. (2020). Effects of the COVID-19 pandemic on university pedagogy: Students' experiences and considerations. European Journal of Education Studies, 7(8).

Kim, S.S. (2021). Motivators and concerns for real-time online classes: focused on the security and privacy issues. Interactive Learning Environments. https://doi.org/10.1080/10494820.2020.1863232

Komljenovic, J. (2021). The rise of education rentiers: digital platforms, digital data and rents. Learning, Media and Technology, 46(3), 320–332. https://doi.org/10.1080/17439884.2021.1891422

Lane, A. (2009). The Impact of Openness on Bridging Educational Digital Divides. International Review of Research in Open and Distributed Learning, 10(5). https://doi.org/10.19173/IRRODL.V10I5.637

Lin, H., Lai, A., Ullrich, R., Kuca, M., McClelland, K., Shaffer-Gant, J., Pacheco, S., Dalton, K., Watkins, W. (2007). COTS software selection process. 2007 Sixth International IEEE Conference on Commercial-off-the-Shelf (COTS)-Based Software Systems (ICCBSS'07), 114–122. https://doi.org/10.1109/ICCBSS.2007.11

Makarova, E.A., Makarova, E.L. (2018). Blending pedagogy and digital technology to transform educational environment. International Journal of Cognitive Research in Science, Engineering and Education, 6(2), 57–65.

Mohamed Hashim, M.A., Tlemsani, I., Duncan Matthews, R. (2022). A sustainable university: Digital transformation and beyond. Education and Information Technologies, 27(7), 8961–8996. https://doi.org/10.1007/s10639-022-10968-y

Morelli, J. (2013). Environmental Sustainability: A Definition for Environmental Professionals. Journal of Environmental Sustainability, 1(1), 2. https://doi.org/10.14448/jes.01.0002

Naveh, G., Shelef, A. (2021). Analyzing attitudes of students toward the use of technology for learning: simplicity is the key to successful implementation in higher education. International Journal of Educational Management, 35(2), 382–393. https://doi.org/10.1108/IJEM-04-2020-0204

OCED (2015). Students, Computers and Learning: Making the Connection. PISA. https://doi.org/10.1787/9789264239555-EN

Ong, D., Moors, T., Sivaraman, V. (2014). Comparison of the energy, carbon and time costs of videoconferencing and in-person meetings. Computer Communications, 50, 86–94. https://doi.org/10.1016/J.COMCOM.2014.02.009

Paredes-Canencio, K.N., Lasso, A., Castrillon, R., Vidal-Medina, J.R., Quispe, E.C. (2024). Carbon footprint of higher education institutions. Environment, Development and Sustainability.

Purvis, B., Mao, Y., Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. Sustainability Science, 14(3), 681–695. https://doi.org/10.1007/S11625-018-0627-5/FIGURES/1

Richter, T., Baum, S., Böhmer, S., Klemenjak, S., Roettgen, A., Stich, C., Vahl, M., Westerfeld, F. (2019). Digital transformation in higher education: Selection, test and acquisition of a business support system - experiences from the field and lessons learned. Proceedings of the 12th International Conference on Education, Research and Innovation (Seville), 1826–1836. https://doi.org/10.21125/iceri.2019.0516

Roy, R., Potter, S., Yarrow, K. (2008). Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems. International Journal of Sustainability in Higher Education, 9(2), 116–130. https://doi.org/10.1108/14676370810856279/FULL/PDF

Saldaña-Durán, C.E., Messina-Fernández, S.R. (2021). E-waste recycling assessment at university campus: a strategy toward sustainability. Environment, Development and Sustainability, 23(2), 2493–2502. https://doi.org/10.1007/S10668-020-00683-4/TABLES/2

Santos, J., Bittencourt, I., Reis, M., Chalco, G., Isotani, S. (2022). Two billion registered students affected by stereotyped educational environments: an analysis of gender-based color bias. Humanities and Social Sciences Communications, 9(1), 1–16. https://doi.org/10.1057/s41599-022-01220-6

Schaffert, S., Geser, G. (2008). Open Educational Resources and Practices. eLearning Papers.

Seale, J. (2013). E-learning and Disability in Higher Education: Accessibility Research and Practice.

Silver, L. (2019). Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally. Pew Research. https://www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/

Smit, B. (2002). Atlas.ti for qualitative data analysis. Perspectives in Education, 20(3).

Soken-Huberty, E. (2022). What is Social Equity? Human Rights Careers. https://www.humanrightscareers.com/issues/what-is-social-equity/

Sterling, S., Orr, D. (2001). Sustainable Education: Re-visioning Learning and Change. Green Books for the Schumacher Society Totnes.

SURF (2023). Joint procurement. https://www.surf.nl/en/it-facilities/joint-procurement

SURF (2023). SURF is the collaborative organisation for IT in Dutch education and research. https://www.surf.nl/en

Timchenko, V.V., Trapitsin, S.Y., Apevalova, Z.V. (2020). Educational technology market analysis. 2020 International Conference Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS), 612–617. IEEE.

TopUniversities (2022). The top UK universities leading the way for sustainability. https://www.topuniversities.com/where-study/europe/united-kingdom/top-uk-universities-leading-way-sustainability

Trevisan, L.V., Eustachio, J.H.P.P., Dias, B.G., Filho, W.L., Pedrozo, E.A. (2024). Digital transformation towards sustainability in higher education: state-of-the-art and future research insights. Environment, Development and Sustainability, 26(2), 2789–2810.

UNESCO (2024). What you need to know about inclusion in education. https://www.unesco.org/en/inclusion-education/need-know

Velazquez, L., Munguia, N., Platt, A., Taddei, J. (2006). Sustainable university: what can be the matter? Journal of Cleaner Production, 14(9–11), 810–819. https://doi.org/10.1016/J.JCLEPRO.2005.12.008

W3C (2016). Accessibility, Usability, and Inclusion. https://www.w3.org/WAI/fundamentals/accessibility-usability-inclusion/

Waas, T., Hugé, J., Verbruggen, A., Wright, T. (2011). Sustainable development: A bird's eye view. Sustainability, 3(10), 1637–1661. https://doi.org/10.3390/SU3101637

Warfvinge, P., Löfgreen, J., Andersson, K., Roža, T., Åkerman, C. (2022). The rapid transition from campus to online teaching—how are students' perception of learning experiences affected? European Journal of Engineering Education, 47(2), 211–229.