Annex B. Guidelines for institutions to support digital infrastructure investment

Introduction

Croatian higher education institutions can benefit from information on best practices and principles to develop institution-level "blueprints" for smart investments in digital infrastructure. These guidelines are intended to provide such insights. They should be read and followed in conjunction with the accompanying guidelines on developing institutional strategy for high-quality digital education, also developed as part of the project (Annex A). They are based on best international practice in investing in digital infrastructure, a diagnostic report on digital maturity in Croatian higher education institutions (Chapter 3) and principles on investment in digital infrastructure in Croatian higher education prepared by the OECD as part of the project (Chapter 4). In Chapter 4, and in these guidelines, digital infrastructure is defined as follows:

> *Digital infrastructure brings together and interconnects physical and virtual technologies and associated supports, enabling higher education institutions to facilitate high quality education and research in an evolving digital landscape*

Higher education institutions across Croatia vary in their governance structures, their ability to access funding streams for digital infrastructure, and the capacity and availability of their staff for professional planning and management of infrastructure projects. These guidelines can help institutions to evaluate the current status of their digital infrastructure and prepare blueprints for successful investments, accounting for resources available within the institution and resources provided centrally to Croatian higher education institutions by public authorities (for example, through CARNET). Five key elements of investment strategy are covered by these guidelines:

- linking investment approaches with the wider digitalisation agenda;
- understanding the institution's starting point;
- evaluating and prioritising infrastructure needs;
- procuring and financing infrastructure acquisition;
- planning for integration, support and maintenance.

After individually analysing each of these elements, these guidelines offer more specific factors to consider when investing in different categories of digital infrastructure (networking, on-campus technical equipment, end-user hardware, software, support and capability).

Who are these guidelines for?

These guidelines are intended primarily to provide a reference to groups of decision-makers and leaders in individual Croatian higher education institutions who are responsible for making investments in different elements of digital infrastructure. Nevertheless, the guidelines stress the importance of making decisions on digital infrastructure that are aligned with wider institutional, national and international orientations for digitalisation in higher education. Alignment of strategy and investment decisions can support coherence and interoperability of technology and help to avoid the pitfalls associated with individuals or small groups

of people acting alone when making decisions about digital infrastructure. Some of the questions raised in the guidelines will therefore require wider consultation and discussion across the institution.

How should these guidelines be used?

The guidelines are designed to support deliberative processes related to the investment of digital infrastructure in higher education institutions across Croatia. Their objective is not to serve as a "one-size-fits-all" prescription, but to support institutions to develop their own investment practice blueprints considering available knowledge on best practices for each element of investment. The word "blueprint" is chosen to highlight a desired convergence of good practice across the institution, where the characteristics of individual investments will vary but all investments are planned and developed according to the considerations laid out in this document.

The guidelines can be used as a tool to validate and shape proposed institution-level investment strategies, highlighting areas for improvement both in the infrastructure and in related institutional practices. They can be used to stimulate internal discussion on important issues related to digital infrastructure, and as a basis for validating and improving general investment strategies.

Five elements of investment strategy for digital infrastructure

Element One: Linking investment approaches with the wider digitalisation agenda

Digital infrastructure investment decisions should be integrated into a wider institutional plan for the improvement of digital teaching and learning. Annex A of this report provides guidelines for setting institution strategy for developing high-quality digital teaching and learning, and bringing together staff, students and institution leaders in a collaborative and cyclical improvement process. This wider improvement process can be instrumental in informing needs and priorities for digital infrastructure and can promote understanding of the resource channels available to support new investments. It is therefore recommended that these guidelines are read in conjunction with the guidelines in Annex A.

Understanding the broader context before making digital infrastructure investment decisions ensures awareness of wider policies, available support, and potential resources to harness from policy and institutional spheres. These resources may include incentives, advisory services, or access to knowledge on best practices and user perspectives on relevant technologies.

Decision-makers with a deep knowledge of the wider agenda will be able to create a better investment approach that can accurately pinpoint "where to innovate and where to follow" (Jisc, 2020[1]). Institutions have limited financial and human resources to spend on digital infrastructure, and therefore must find the best balance between aligning with wider systemic incentives and knowledge of proven technologies and creating a digital infrastructure to meet their unique needs and goals.

Key questions for discussion and reflection

Q1 – What digitalisation strategies and policies already exist that may have implications for my digital infrastructure investment? In my institution? In Croatia? In Europe?
Q2 – Are there other types of institution or system-wide regulations or policy initiatives in place that may affect current and future digital infrastructure investment decisions (e.g. procurement, accounting, recruitment)?

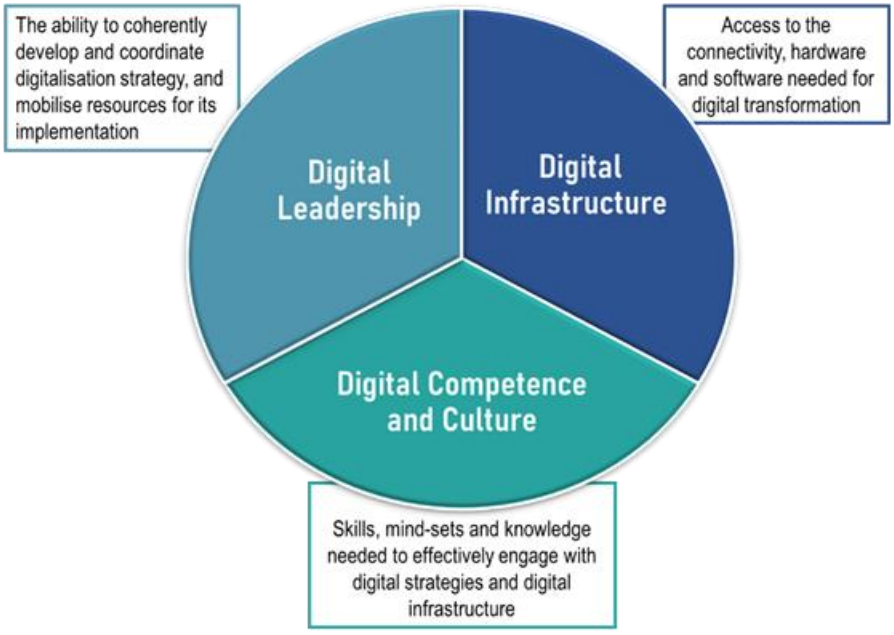
Element Two: Understanding the institution's starting point

Each institution will undertake investments in digital infrastructure from different starting points. Some institutions may have already invested substantially in building investment capacity and strategy, particularly following the COVID-19 pandemic and 2020 earthquakes, which created a long period of forced dependence on digital teaching and learning in Croatia. Other institutions may still have very limited infrastructure, and/or limited capacity to invest resources in improvements. Others still may be dealing with substantial legacy issues from previous investments that were strategically unsound, leading to a mixture of technologies lacking interoperability and efficiency. A comprehensive assessment of the starting point of the institution's digital infrastructure is vital for assessing future needs and priorities.

In Croatia's education system, there is a growing focus on the concept of "digital maturity" of institutions. In Croatian schools, digital maturity has been defined in the national e-School project in terms of maturity across different areas, comprising ICT infrastructure, but also leadership, the use of ICT in teaching and learning, competence and culture. Croatian authorities are working on a similar concept of digital maturity for higher education institutions, and the current OECD project is providing analysis to support this concept. It advocates for a simpler and more flexible specification of digital maturity for higher education institutions compared to schools, on the basis that they tend to be more internally heterogeneous, with different levels of maturity across different departments, disciplinary areas and staff and student categories.

Three key interlinked elements of digital maturity are highlighted in the proposal developed by the OECD: digital leadership, digital infrastructure and digital competence and culture (Figure B.1). This proposal is intended as a starting point for developing a national digital maturity framework for higher education institutions in Croatia, led by CARNET as part of the national e-Universities project (CARNET, 2022[2]).

Figure B.1. A conceptual framework for digital maturity evaluation and improvement



While these guidelines are focused on digital infrastructure, an understanding of the starting point needs to also consider the presence and strength of each of the two other elements of digital maturity. Digital infrastructure alone cannot be effectively deployed without the competence of staff and students to engage with it, and their acceptance of digitalisation as an effective means of improving teaching and learning. In

turn, this competence and culture is best promoted through strong leadership and championing of digitalisation at a high level. Reflecting on these questions, as well as the current state of the infrastructure, can support the analysis of needs and prioritisation of resources.

Chapter 3 of this report, on digital maturity in Croatian higher education institutions, suggests indicators that could be used by an institution to assess its development in each of the digital maturity elements. The questions below can also be used to reflect more deeply on the status quo of the institution regarding digital maturity.

Key questions for discussion and reflection

Q1: Where does the locus of leadership lie in digitalisation within my institution? Are there individuals with clear roles and responsibilities for leading and championing digital issues (e.g. Chief Information Officer or Chief Technology Officer)?

Q2: Who makes decisions on investment in digital infrastructure? How are such investments monitored within the institution?

Q3: What is the general attitude of colleagues and staff throughout the institution with respect to digitalisation? Is there broad scepticism, indifference or enthusiasm? What is driving these attitudes?

Q4: What is our assessment of the current quality of each element of digital infrastructure? In which areas do we currently have adequate technologies, and in which areas do we lag?

Q5: Are there risks associated with the technologies we are currently using (e.g. obsolescence, risk of technology failure, funding risks)? What will be the impact on the institution if these risks are realised? Is there broad awareness and understanding of the risks?

Q6: What have we already achieved in terms of successful technology investment and implementation? How did we do this, what were the success factors, and how can we replicate it again for future investments?

Element Three: Evaluating and prioritising infrastructure needs

Following an assessment of the status quo, a clearer understanding should begin to emerge about the most urgent requirements for digital infrastructure investment. Successful acquisition of digital education infrastructure implies having sufficient information, capacity, and skills to navigate the wealth of choices of digital products, services, and tools. Infrastructure purchasing decisions should also reflect a comprehensive understanding of student and staff needs, to ensure that acquired digital tools are fit for purpose.

Evaluating needs and prioritising infrastructure investments can be carried out using different methods. If investments are planned in the context of a wider institution-level strategic development process, then feedback from that process should already provide some indication of the most urgent needs and priorities from the point of view of users. This information could be complemented in several ways to ensure that widespread views of the user base are considered. For example, a survey of users could be carried out to find out their preferences and ensure that assumptions being made about their needs reflect their actual situation. Alternatively, user groups could be consulted in workshops or seminars aimed at promoting their most pressing requirements.

As well as the stated needs of users, other forms of evaluation include assessing and comparing alternative potential investments according to a set of standard criteria. As an example, the box below proposes a set of general questions for evaluating and prioritising between alternative investments based on the OECD Recommendation of the Council on the Governance of Infrastructure (OECD, 2020[3]), the G20 principles for Quality Infrastructure Investment (G20, 2019[4]), and the United Kingdom's guidelines for investment in education technology (Crown Commercial Service, 2022[5]).

Key questions for discussion and reflection

Q1: What is the envisaged social impact of the infrastructure? Will the infrastructure contribute to widening equity of participation or completion, and if so, how?

Q2: To what extent is the infrastructure investment linked to stated institutional or systemic goals and objectives such as its digital education strategy or teaching and learning strategy (where they exist)?

Q3: How is the infrastructure expected to improve the status quo? How will it positively affect the activities of the institution? Is the size of the investment proportional to the anticipated positive impact, as indicated by available evidence?

Q4: How many or what share of users of the institution will benefit from the infrastructure deployment?

Q5: What is the anticipated lifecycle of the infrastructure? Can it be deployed for other functions or uses once it has fulfilled its intended primary purpose?

Q6: What will be the impact of the infrastructure on environmental sustainability goals? Will it contribute to their achievement or detract from them?

Q7: What are the estimates of ongoing expenditure required to maintain, support and upgrade the equipment? To what extent is this expenditure offset by estimated cost savings associated with deployment of the infrastructure?

Q8: How does the infrastructure adhere to hardware or software interoperability or data portability standards? How well does the planned investment integrate with existing and future technologies?

Q9: To what extent has proof of demand been established for the infrastructure? How has its fitness for the intended purpose been evaluated?

Q10: Are there risks associated with the planned infrastructure (for example, security, ethical risks or risks of failure)? If so, have adequate mitigation measures been developed and validated?

Element Four: Procurement and financing of infrastructure

Decisions about infrastructure investments extend to the resourcing of the infrastructure. Raising and spending funding on infrastructure is carried out in an environment with many competing needs for financing, and in a market environment that often has asymmetric information between technology providers and buyers. Most higher education institutions have several potential public and private funding streams to resource investments in digital infrastructure. Overdependence on one source of financing creates risks, and as is the case for financing all the institution's activities, efforts should be made to cultivate as many revenue and financing streams as possible to fund digital infrastructure.

Some types of physical equipment and Internet connectivity have traditionally been provided to Croatian higher education institutions either through a direct NREN service from CARNET, or through project-based funding from public authorities. CARNET alone provides approximately 40 distinct services to more than 200 000 users in higher education and research organisations (Géant, 2022[6]). CARNET and other important actors, such as SRCE (University Computing Center of the University of Zagreb) are continuously enhancing technological, and capacity-building supports to institutions. Institutions therefore use their expertise as the first port of call when considering forms of technology enhancement. Considering additional current and future investments through the e-Universities programme, CARNET and its partners are likely to further increase the range of services they provide, and as such should represent an important primary source of advice for institutions on infrastructure projects.

As mentioned, some forms of digital infrastructure may be financed from project-based or targeted public funds. Although once-off funding provides a vital means for institutions to fund large infrastructure projects, attention must be paid to the need for continuing recurrent funding for infrastructure support and

maintenance. Planning and resource mobilisation for digital infrastructure increasingly needs to be considered as a multi-year rather than an annual process, or a singular investment in a particular type of equipment.

Another important consideration for institutions is whether the required infrastructure should be purchased and owned directly by the institution, or whether other forms of access to the technology are more appropriate or cost-effective. For many categories of infrastructure, digital equipment leasing, virtualisation and cloud-based applications are converting traditional capital investment to current expenditure with possible implications for future funding models. In this way, institutions can avoid large upfront costs, but also need to plan for perpetual recurrent expenses. The extent to which institutions can assess the relative merits of such investments may vary, depending on previous experience, access to market information and in-house expertise. This is an area in which collaboration and knowledge-sharing among institutions can pay substantial dividends.

Another area where institutions can most benefit from wider collaboration is procurement. Procurement is a commercially confidential process between higher education institutions and suppliers. Pricing details are often withheld, and buyers may have limited insight into the features and potential risks of the technology before it is purchased. As a result, institutions may purchase technology that is ineffective, difficult to support locally, or incompatible with existing infrastructure. Managing these risks requires collaboration and information-sharing among institutions, either through collective purchasing to increase buying power, or through systematically sharing user experiences of purchased technologies.

An alternative model for investing in digital infrastructure can be pursued at the system level, through direct tendering and provision of the resource by public authorities to higher education institutions. Central procurement provides opportunities for higher education institutions to acquire secure and stable high-capacity network connections with accompanying management services and tools. Such direct provision can be especially beneficial for smaller institutions with less access to financial resources from private sources, or with fewer staff with strong digital capabilities. While institutions may often communicate needs to governments or technology providers on an individual level, there is a stronger possibility that collective efforts to identify common needs and solutions will be resourced, either publicly or through more robust partnerships with educational technology providers.

Finally, partnerships between higher education institutions and those outside the sector (such as start-ups, technology companies and government) can facilitate innovation, particularly for unproven technologies. Emerging technology companies benefit from the opportunity to test novel tools or products, while institutions can have a greater role in shaping technologies to meet their specific needs (OECD, 2019[7]).

Key questions for discussion and reflection

Q1: What sources of revenue are available for financing our digital infrastructure projects? Are there additional potential sources that are not being exploited?

Q2: How are ongoing costs for the digital infrastructure being assessed and budgeted? Is the current process adequate, and does it account for the existing and potential future conversion of capital to current expenditure, as well as support and maintenance costs?

Q3: How extensive is our current knowledge and understanding of the education technology markets from which we are intending to procure technology? What is the balance of power and information between us, as the buyer, and the technology vendors with which we engage? To what extent are we aware of the technologies being used in other institutions in Croatia and elsewhere in Europe, and their impact?

Q4: To what extent do we engage in collective procurement? What are the benefits and challenges associated with current procurement processes? How can we improve or extend collective procurement processes?

Q5: What is our current balance between directly owned technology and leased/cloud-based technology? Where would we like this balance to be? What are the advantages and disadvantages for our organisation of outsourcing?

Q6: To what extent are we able to partner with others to improve the efficiency and effectiveness of digital equipment acquisition? Who are our collaborators and potential collaborators? How can we harness the innovative capacity of other sectors to acquire technologies that meet our needs and objectives?

Element Five: Planning for integration, use and support

One of the most persistent current challenges that higher education institutions in Croatia and elsewhere are facing is the availability of staff to support and maintain digital infrastructure. The difficulty of attracting and retaining skilled staff is an ongoing concern for all types of institutions and must therefore be a key element of planning for digital infrastructure investments.

While most higher education institutions in Croatia have in-house support staff to maintain networks, physical equipment and software, an increasing number of institutions also rely on contract staff or external companies. In some European jurisdictions, institutions often outsource key functions, up to and including the provision and support of on-campus local area networks (so-called Campus Network as a Service or CNaaS).

Such externally managed services provide a viable alternative especially for institutions struggling to attract and maintain network engineering and maintenance staff on-site, or that are overdependent on the presence of specific employees to ensure reliable network services (GEANT, 2022[8]). At the same time, many institutions may be reluctant to take measures that can move the operation of essential services beyond their immediate control, or to de-skill or sideline existing staff by taking core tasks out of their hands. Institutions should carefully assess the costs and benefits of outsourcing different elements of digital infrastructure support and maintenance and seek to learn from the experiences of other institutions in Croatia and elsewhere.

Any investment in digital infrastructure only has value if the infrastructure is being used. Bridging equipment gaps is insufficient if students and staff are not empowered to effectively engage with the technologies provided. Many higher education staff members started their careers at times when the penetration of digital technologies in their workplace was limited or non-existent and have faced difficulties adapting to using emerging technologies that are now vital to their role. Moreover, in a context where research performance is often more prominently rewarded than teaching improvement, motivation to make changes may be limited. Incentives to promote engagement with new technologies, advisory supports and training are increasingly fundamental, as institutions become more digitalised. Institutions' plans for procuring new technologies need to consider the extent to which users can and will be willing and able to use the technology.

Institutions also increasingly have the option of engaging NRENS and other public bodies to help improve the digital capabilities of their staff. For example, SRCE provides a substantial training offer to staff across the Croatian higher education system, covering different aspects of e-learning material development and delivery (SRCE, n.d.[9]) and CARNET will offer comprehensive education and training of digital competence of decision makers, teaching staff and IT personnel on a national level as part of the e-Universities project.

A final important consideration is the extent to which the new infrastructure can integrate with the status quo. Ideally, this point should be widely assessed and planned for before investing. The growth of "shadow IT" (where staff ignore the technology provided by their central services in favour of an informal solution to meet their specific need) is testament to how misunderstandings can arise about the usage and

effectiveness of digital technologies. Regular monitoring of user perspectives and usage patterns is vital to ensure the technology is enhancing activities and not impeding them.

Key questions for discussion and reflection

Q1: Are staff available to maintain and support new digital technologies? To what extent will the new technology affect (positively or negatively) their workload?

Q2: Is external provision of support services a viable or suitable option for our institution for certain types of technology?

Q3: Is training required for the new infrastructure? If so, how, when, how often and by whom will users be trained?

Q4: How will usage patterns and user perspectives of the utility of the infrastructure be assessed? How will the status quo be adapted if the infrastructure is not being used or supported as intended?

Guidelines for specific infrastructure types

The elements listed above are applicable to all types of infrastructure investment. However, some more detailed guidelines can be specified according to the type of infrastructure investment under consideration. The following sections outline some specific guidance related to four types of infrastructure: networking, on-campus technical equipment, end-user hardware, and software. These specific guidelines reflect the analysis and conclusions drawn in the technical report on digital infrastructure prepared for this project (see Chapter 5).

Investing in network connectivity

Backbone Internet networks are the core network for the higher education system, enabling higher education institutions to connect to the Internet. NRENs are in most cases the sole providers of fixed and wireless high-capacity Internet connectivity for higher education and research institutions in Croatia (through CARNET) and throughout Europe (Géant, 2020[10]). The backbone network connectivity is distributed through higher education campuses by means of on-campus networking, including private wired and wireless, and public networks.

Internal wired campus networks in higher education institutions are often not designed to carry the higher speeds provided by the entry point from the NREN to institutional premises. Upgrades to the backbone Internet connection can only be of value to higher education institutions if internal campus networks are adequately equipped to take advantage of the higher speeds provided by the upgrade. Therefore, one of the main tasks of institutions' ICT function is the maintenance and upgrade of on-campus networks.

The e-Universities project currently being rolled out by Croatian public authorities is expected to lead to campus network upgrades for most institutions. The project encompasses the upgrading of the access network, campus network and backbone, as well as the design and implementation of passive and active networks at the campuses of higher education institutions (CARNET, 2022[2]). However, it is likely that supplementary upgrades will continue to be implemented by higher education institutions, as existing equipment ages and connectivity needs evolve.

Monitoring existing network traffic levels can provide the clearest indication of where current saturation points lie and offer a basis for estimating future bandwidth needs and pinpointing where future upgrades are most urgently needed. Students are often most aware of important locations on campus where network connectivity is suboptimal, and efforts should be made to systematically gather their knowledge of the campus network. Estimates of future needs should also account for certain new realities, particularly since the onset of the COVID-19 pandemic in 2020. These realities include:

- an emerging consensus that distinctions can no longer be drawn between disciplines in terms of their network connectivity requirements. Previous differences between disciplines in terms of use of digital tools are quickly breaking down as blended or online learning becomes commonplace in almost all subjects.
- the emergence of synchronous videoconferencing (Zoom, Teams etc.) during the era of emergency online learning that has become embedded as the "new normal", with an expectation of continuous availability of ad-hoc connectivity for online and hybrid meetings, lectures and events.
- the potential need for greater bandwidth requirements in classrooms, where teaching and learning may make greater use of live streaming or audience response systems.
- an increasing need across all disciplines for specialist software and higher computing power, in both teaching and research activities. The increasing use of technologies such as augmented reality and virtual reality in a wide range of disciplines (creative arts, archaeology, medicine etc.) is contributing to the need for more bandwidth and computational capacity.

Institutions dealing with these challenges will need to strike a balance between managing expectations of students and staff, using existing resources as efficiently as possible, and devoting resources to connectivity upgrades. Institutions' investment plans for their connectivity infrastructure need to react to such issues as moving campus locations, or reducing enrolments, a phenomenon observed in many institutions in recent years. Network user behaviour on campus has proven challenging to predict (Evans, 2020[11]), requiring institutions to pay more attention to methods for anticipating future connectivity investments.

As mentioned in element five above, there is a growing trend in some European countries towards CNaaS, the direct provision and support of on-campus networking by an external body to the institution (including NRENs). CNaaS can be a solution for institutions with limited on-site IT support capacity and does not necessarily entail deskilling or employment loss for current on-site staff. CNaaS may be used as a complement to on-site management, or to reduce pressure and workload for on-site staff (GEANT, 2022[8]).

Key questions for discussion and reflection

Q1: To what extent is current network connectivity able to meet the needs of users in different areas of the institution? Where and what are the challenges and bottlenecks? Could these be resolved by means other than upgrading connectivity (e.g. reorganising activities or implementing acceptable use policies)?

Q2: Which methodology is in use to predict future needs for connectivity? Does the approach account for important factors such as the growth of bandwidth intensive technologies and activities across disciplines, the requirements for online teaching, and expected surges and periods of network congestion at certain periods or times of the year?

Q3: To what extent is the current campus network infrastructure (both physical and logical) fully understood and documented? How can the documentation of the existing network be improved? How are ad-hoc technical changes managed and documented?

Q4: To what extent are existing staff trained in emerging network equipment and technologies that can support a more efficient and effective infrastructure? Are CNaaS services a viable option to alleviate pressure and ensure persistent support is available for the campus network?

Q5: In cases of outsourcing, how is the critical intellectual property of the institution identified and protected?

Q6: How resilient and secure is the current network infrastructure? What measures are in place to deal with failures or attempts to breach cybersecurity? Are emerging best practices for network management in place or under consideration (e.g., backup connections, redundancies in the network topology, computer aided orchestration and/or automation)?

Investing in on-campus technical equipment

The two most common types of on-campus technical equipment are server hardware and audio-visual equipment. This section outlines some of the key considerations for institutions when planning investments in these equipment categories.

There is a common perception that, as time goes on, on-campus server hardware is being phased out in favour of cloud services, although the process is slow and uneven across countries. As server applications transition to the cloud and NRENs enhance network resilience and speed, institutions can better support staff in adapting to cloud-based services. Cloud services are more equipped to handle rapid, unforeseen surges in connectivity demand, like during the COVID-19 pandemic, which is not economically feasible with on-premises server capacity. Despite the growth in cloud services, many higher education institutions continue to host student-facing systems on-premises, necessitating upgrades to on-campus hardware due to increased online service demand.

When upgrading server hardware, resilience and security are crucial considerations, as well as cost. Cybersecurity is a significant global challenge for higher education systems, posing a prominent risk to server security. Physical security of servers is also essential, requiring on-campus measures if cloud technology isn't adopted.

Another vital category of on-campus equipment is audio-visual equipment, such as projectors, electronic whiteboards, monitors, videoconferencing and lecture capture devices, voting and feedback tools, and virtual and augmented reality technologies. A top priority for Croatian higher education institutions is ensuring access to dedicated equipment for high-quality digitalised teaching material production and hybrid or online lecture delivery.

Key questions for discussion and reflection

Q1: Which combination of on-campus and cloud-based server equipment is likely to best serve the institutions' current and future needs?

Q2: To what extent is existing server capacity adequate for the institutions' needs? What is the most resilient and secure means of upgrading capacity?

Q3: For on-site upgrades to server infrastructure, is there adequate provision for the security of the equipment against cyberattacks (e.g. multi-factor authentication, VPN, end-user device management protocols), and against physical risks (e.g. secure storage, access control, alarms, flood and fire protection)?

Q4: Is there adequate on-campus access to professionally equipped spaces for developing digitalised teaching material? How are views and perspectives on this question being collated? To what extent are current facilities being used, where they exist, and what are their deficiencies?

Q5: Does the planned investment in audio-visual equipment account for the estimated useful life of the technology, or the risk that the technology will quickly become obsolete? Do planned investments consider the speed at which audio-visual technology develops, and emerging technologies on the near-term horizon that may be more efficient or have a longer useful lifetime? Is there an exit strategy in place to allow for low-cost future pivots from or replacement of the planned technology?

Q6: How many current and future staff and students are likely to benefit from the audio-visual technology currently under consideration for investment, over its lifetime? Does the foreseen level of use justify the cost of the technology? Are other alternatives available, or can the cost and use of the equipment be more widely shared across other areas of the institution, or used to generate additional revenue (e.g., by hosting external events)?

Investing in end-user hardware (staff and students)

Equitable and stable access to digital devices for teaching and learning purposes varies among higher education staff and students. Depending on available resources, institutions can choose between implementing widespread Bring Your Own Device (BYOD) policies or providing institution-purchased equipment to as many users as possible. BYOD as a substitute for institution-provided equipment only works if personal devices can interoperate with the main institutional systems. Furthermore, personal devices may lack required safeguards, leading to privacy and security issues (van der Vlies, 2020[12]).

Institutions can also invest across a wide spectrum of end-user devices, such as laptops, desktop computers or tablets. Modern laptops are more portable, with in-built peripherals, longer battery life, and have become powerful enough to run more demanding applications. At the same time, desktops on campus are likely to remain ubiquitous, particularly in student computer labs, for several reasons: they are more ergonomic, and offer higher specifications, higher connection speeds, managed access to specialist hardware, software and content, larger screens, and better security compared with personal devices. Centrally managed student computer clusters also allow institutions to benefit from bulk purchases, and benefit a larger number of students, compared to directly providing devices to individual students.

As with other forms of equipment, consideration needs to be given to the lifespan of equipment, after-sales support and warranty of devices, and on-campus staff support to maintain the devices and support users.

Key questions for discussion and reflection

Q1: Is current provision of end-user devices by the institution adequate to support teaching, learning, research and operational needs? How are gaps identified? Are current methods for assessing and prioritising needs adequate?

Q2: How are the identified needs translated into equipment specification requirements, and balanced against equipment costs? Can these methods be streamlined or improved?

Q3: How is the institution working to reduce the cost of purchasing end-user devices? Is the institution benefiting from or pursuing collective bulk procurement of devices with other institutions, where feasible?

Q4: What helpdesk supports are in place for students and staff using BYOD or institution-provided end-user devices? Will additional support be required in the event of further equipment purchase? If so, how will these support needs be met?

Investing in software

The main categories of software in higher education institutions, as in most large organisations, are central applications intended for widespread use, and specialist applications needed by some categories of staff. The latter category can be an important priority for resources in higher education institutions, given the extent of specialised research and discipline-specific teaching that naturally forms part of their activities.

Central applications, like learning management environments, are important investment targets due to their widespread use and cost-effectiveness. In Croatia, the Moodle VLE is extensively used, with some institutions further adapting it or opting for alternative systems.

End-user software is also an important target for investment, in particular productivity software such as office suites and creative suites used for presentation and visualisation of material. Alongside widely used productivity and creative suites, numerous specialist end-user software applications support teaching, learning, research, and administrative activities for students and staff in higher education institutions. Examples include coding software, e-learning content creation tools, and specialist engineering applications.

A crucial consideration for institutions investing in software is the extent to which they can or should use free software and open-source applications. Open-source software offers low or no cost and potential customisation, but also presents challenges like interoperability issues, limited customer support, and concerns about its lack of use in the businesses and industries students will enter after graduation.

Decisions about the provision of widespread productivity software are generally more straightforward. There is a strong case for investing in such software as it is used almost ubiquitously and forms the basis for many learning experiences, work activities and communications throughout the institution. In Croatia, Microsoft Office 365 is widely used, and the Ministry of Science and Education has financed the provision of the software throughout the higher education system. Decisions become more complex for specialist software, which can be significantly more expensive and less widely used. With reliable internet connectivity, cloud services allow for continuous subscription payments instead of one-off investments, but institutions may still face unplanned cost increases.

It is therefore important for institutions to carefully examine propositions for investment in specialist software, working with users to explore planned usage of the software, looking for means to minimise costs where possible, and avoiding vendor lock-in. Investment of finite funds in software is best made based on demonstrable proof of widespread need and demand for all elements of the proposed software solution.

A final concern for institutions investing in software is the extent to which the software will integrate with existing central software and other specialist software. A lack of interoperability increases costs associated with supporting the software and limits its capacity to support insights and improvements to teaching, learning and administrative processes (e.g., for learning analytics). Institutions have a role to play in surmounting interoperability challenges, by supporting the development and adoption of open-source software where possible and promoting the adoption of open standards for interoperability. This may cover learning platforms, learning analytics, integrated assessment tools and standards (1EdTech, 2022[13]).

Key questions for discussion and reflection

Q1: How many individuals will benefit from the software investment, and what will be the benefits, compared to the status quo? What is the cost per user, and the assessment of positive impact for the cost outlay?

Q2: Are robust open-source alternatives available for specific software packages? Alternatively, are there ways to reduce the cost of software through collaborative purchases, cloud-based subscriptions for limited times, or purchasing fewer user licences?

Q3: Are users using a wide range of the software's functionality? Can cost savings be made by purchasing a more basic version of the software?

Q4: What mechanisms exist (outside of vendor sales activities) to learn about relevant and emerging software that may be of benefit to the institution, or provide a more suitable alternative to certain existing software? How can these information flows be improved or expanded?

Q5: What forms of support are available to assist software users, from the vendor or within the institution?

Q6: What are the anticipated costs (financial or other) of exiting from the software or pivoting to different software following purchase? How can these costs be minimised?

Q7: How will the software interoperate with existing applications in the institution?

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