

Proceeding Paper

A Configurable Intelligent Framework for Digital Learning Environment Assessment in Higher Education [†]

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Abstract

Digital transformation has fundamentally reshaped higher education, creating a need for adaptive systems capable of integrating technological infrastructure, learner capabilities, institutional readiness, and learning analytics into a unified decision-support environment. While existing studies predominantly examine online learning from pedagogical or behavioural perspectives, comparatively little attention has been devoted to configurable system architectures that support institutional monitoring and continuous optimization of digital learning ecosystems. This paper addresses this gap by proposing a configurable Digital Learning Capability Assessment Framework (DLCAF), a modular systems framework designed to assess, monitor, and optimize digital learning environments through the integration of infrastructure capabilities, digital literacy, learner motivation, technology acceptance, and institutional performance indicators. The framework employs a layered architecture comprising data acquisition, capability assessment, analytics, decision-support, and feedback modules, enabling flexible configuration according to institutional requirements and educational contexts. To demonstrate the applicability of the proposed framework, a survey involving 220 students from 27 study programs across Croatian higher education institutions was conducted during the COVID-19 digital transition. The empirical findings serve as an application case for validating the framework and illustrating how learner perceptions, technical constraints, institutional support, and digital readiness can be systematically incorporated into an adaptive decision-support process. The results indicate that technical infrastructure, learner motivation, digital competencies, communication quality, and institutional support collectively influence the effectiveness of digital learning environments. The proposed framework transforms these heterogeneous indicators into actionable institutional intelligence that supports evidence-based planning, continuous monitoring, and targeted intervention strategies. By repositioning digital learning evaluation as a systems engineering problem rather than solely an educational assessment exercise, this work contributes a reusable and extensible framework that can be deployed across diverse higher education environments. The architecture provides a foundation for future integration of artificial intelligence, learning analytics, predictive modelling, and adaptive recommendation mechanisms, supporting the development of intelligent digital learning ecosystems capable of continuous improvement and institutional decision support.



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1. Introduction

The COVID-19 pandemic profoundly disrupted higher education and accelerated the transition from face-to-face teaching to online learning [1]. In Greece, the Hellenic Open University is the only university that provides recognised degrees exclusively through distance education [2]. Overcoming challenges and pursuing current trends, a great number of individuals are transitioning careers and adopting the stance that learning is a lifelong process, making these the essential aspects of the learning trends. Available technological tools frame our cognitive activity by having an impact on the brain and altering its processes of learning, ultimately supporting the learning experience [3]. ICT tools are increasingly assuming a central role in education [4]. Current teaching methods have adopted online learning as a trend. The contemporary teaching environment is witnessing a growing trend in online learning, accompanied by an increase in the use of ICT and the implementation of modern pedagogical methods. Direct results of introducing ICT in learning include novel educational methods such as online learning courses, making it possible for remote students to attend and learn without necessarily having a mentor present. Online learning in institutions of higher education is the basis of this study—specifically, the examination of its pros and cons. What is crucial to analyse is the teaching practice of Croatian universities amid the COVID-19 pandemic, specifically with regard to the implementation of communication and information technology. Having faced many challenging alterations, providing continuous quality in teaching is crucial, especially improving the overall quality of courses to reach the appropriate standards and enhance methods of teaching, e.g., achieving easier navigation through remote learning for both teachers and students. The spread of COVID-19 throughout the world was swift and unpredictable; for Croatia, it changed day-to-day life as people knew it as of February 2020, when it appeared in our country. The most significantly impacted sectors were those of knowledge transfer (i.e., education) and any revolving around services and experiences (such as tourism, briefly).

Despite considerable progress in understanding the pedagogical, behavioural, and organizational implications of online learning, the majority of existing research evaluates digital education from an application perspective rather than a systems perspective. Most studies focus on learner satisfaction, technology acceptance, instructional effectiveness, or institutional readiness independently, while comparatively fewer studies investigate how these heterogeneous dimensions can be integrated into a configurable computational framework capable of supporting institutional decision-making. As digital learning environments become increasingly dependent upon interconnected technological services, learning management platforms, communication infrastructure, and institutional information systems, there is a growing need to conceptualize digital learning as a complex socio-technical system whose individual components continuously interact and influence educational outcomes.

From a computer science perspective, digital learning environments can be viewed as distributed information systems that acquire, process, and transform heterogeneous educational data into actionable institutional knowledge. Such systems must simultaneously accommodate multiple sources of information, including learner characteristics, technological infrastructure, digital literacy indicators, institutional policies, communication quality, and learning analytics. Managing these interconnected components requires more than descriptive statistical analysis; it requires an extensible systems architecture capable of integrating diverse data sources, supporting configurable evaluation processes, and generating adaptive recommendations that assist institutional stakeholders in improving educational performance. Consequently, the design of reusable computational frameworks has become an increasingly important research direction for supporting digital transformation within higher education.

To address this challenge, this paper proposes a Digital Learning Capability Assessment Framework (DLCAF) that provides a modular architecture for integrating technological, institutional, and learner-related indicators within a unified decision-support environment. The proposed framework is organized as a collection of interoperable functional modules responsible for data acquisition, capability assessment, institutional analytics, recommendation generation, and continuous monitoring. Each module performs an independent computational function while exchanging standardized information with adjacent modules, thereby enabling scalability, extensibility, and adaptation to different higher education environments. Unlike conventional evaluation approaches that rely exclusively on descriptive interpretation of survey outcomes, the proposed framework transforms educational indicators into computational inputs supporting systematic institutional assessment.

An important characteristic of the proposed framework is its configurability. Higher education institutions differ considerably with respect to technological infrastructure, digital maturity, academic programs, learner demographics, and organizational policies. A fixed evaluation model therefore cannot adequately represent the operational diversity of contemporary universities. The proposed framework addresses this limitation by enabling institutions to configure assessment parameters, weighting schemes, capability thresholds, and recommendation policies according to local operational requirements while maintaining a common architectural structure. This design enables the framework to support a wide range of institutional contexts without requiring modification of its underlying computational architecture.

Within the proposed framework, digital learning capability is interpreted as the result of interactions among several complementary dimensions, rather than as an isolated educational construct. Infrastructure reliability, learner digital literacy, institutional readiness, communication effectiveness, motivation, technology acceptance, and instructional support collectively contribute to the overall capability profile generated by the system. Instead of analysing these variables independently, the framework evaluates their combined influence through an integrated processing workflow that supports continuous monitoring, comparative institutional assessment, and evidence-based decision-making. This systems-oriented interpretation allows educational data to be processed in a manner consistent with modern software frameworks designed for adaptive decision support.

The empirical investigation conducted among Croatian higher education students serves as the validation environment for demonstrating the operation of the proposed framework. The survey data are not viewed solely as descriptive research outcomes but as representative input variables processed by the capability assessment workflow. Through this interpretation, the study illustrates how learner perceptions, technological conditions, institutional characteristics, and digital literacy indicators can be transformed into structured system knowledge that supports institutional evaluation and continuous improvement. Accordingly, the primary contribution of this work lies in the proposed configurable framework, while the Croatian case study provides empirical evidence demonstrating its applicability within a real higher education environment.

2. Literature Review

Adaptation in the sense of carrying out the entire teaching process emphasizes the valuable abilities of teachers and students. The new reality is an organizational challenge. During the pandemic, teaching policies have been the focus of debate, mostly framed by government frameworks for dealing with sufficient forms, but with different effects, defined by the predominance of a public or private educational framework within vocational or higher education. The level of acceptance of distance learning in higher education has been affected by the pandemic. Even though its use extends over 20 years [5,6], motivated or

forced by the existing situation in which teachers have developed their digital competences, e-learning in the perspective of the future will be defined not only by digital possibilities in the form of digital skills and the ease of use of digital tools in mastering new teaching methods [7], but also by students' ability to accept them, often preferring classic teaching methods in direct contact with teachers.

The efficiency of learning when acquiring knowledge and learning through non-verbal communication is very important. Face-to-face communication allows teachers and students to exchange experiential, emotional, and non-verbal cues, thereby creating a more supportive and interactive learning environment. However, we learned a lot from the uncertainties caused by COVID-19, finding advantages of ICT in mastering digital competencies that are very important in a broad area of application. Sensitive areas of education for some seemed to be polygons under which the competencies of teachers and students are matched, mastering the application of innovative tools in a short time. Under normal circumstances, digital transformation would be expected to progress gradually as both teachers and students acquire ICT skills and experience its benefits. The fundamental goal of education, namely knowledge acquisition, should not be replaced by or confused with proficiency in using innovative tools.

Recent advances in digital learning have shifted research attention from the simple deployment of online learning platforms toward the design of integrated educational information systems capable of supporting adaptive institutional management. Modern higher education environments operate as complex socio-technical ecosystems composed of learning management systems, communication platforms, institutional databases, assessment services, and digital collaboration tools that continuously exchange information across multiple organizational levels. Rather than functioning as isolated software applications, these components collectively form distributed systems in which educational data are generated, processed, and consumed throughout the learning lifecycle. Consequently, research has increasingly emphasized the importance of system architectures capable of integrating heterogeneous educational resources into unified operational environments that support scalability, interoperability, and continuous service improvement.

From a software engineering perspective, modular system architectures provide significant advantages over monolithic implementations because individual functional components can be independently developed, maintained, configured, and extended without affecting the overall system operation. Such modularity enables educational institutions to adapt digital learning services according to changing technological requirements while preserving compatibility with existing infrastructure. Layered architectures further improve maintainability by separating data acquisition, analytical processing, business logic, and presentation services into distinct computational layers. This architectural separation facilitates system evolution and enables future integration of emerging technologies—including artificial intelligence, predictive analytics, intelligent tutoring systems, and automated decision-support services—without extensive redesign of the underlying framework. Layered and modular architectures improve maintainability, scalability, and interoperability by separating computational responsibilities into reusable components [8].

Open-source software platforms provide access to their source code and can be adapted to an organisation's specific needs. Coming from the Moodle program, and similarly customized for user specific user requirements, the Merlin online learning system offers modules for university online programs and projects, including a Merlin online learning program, a webinar, and an e-portfolio system linked to the ISVU (Higher Education Information System) system. The ISVU undergoes regular updates to cater to users' needs more efficiently [9]. Moreover, online learning has the potential to become a tool that universities can adopt to tailor their learning programs and make them more flexible,

using content provided by companies for students, and improving their understanding of business practices and concepts (business games and tools, real-case studies) [10]. What is in store for the classical educational method of teaching and learning in person, with students and teachers sharing the same space? It seems that a combined approach is the best solution. This is known as the blended learning model (blended learning), which benefits from both approaches. A blended model is best for the introductory section of online university courses, where novel elements are being acquired in the traditional, in-person method, avoiding confusion in shifting from one state to another. Following this pattern, failed attempts to introduce new methods can be avoided, ultimately increasing the quality of teaching and content [11]. Development of communicative competence is actively promoted by using interactive teaching methods [12].

Service management programs and paid learning programs as well as open-source programs exist on the market, enabling the avid learner to keep up with any e-learning system, where both exist and develop at the same time [13].

Although numerous learning management systems provide comprehensive educational services, they generally focus on operational functions such as course management, communication, assessment, and content delivery. Comparatively fewer studies investigate configurable analytical frameworks capable of continuously evaluating institutional digital learning capability through the integration of technological, organizational, and learner-related indicators. Decision-support systems have long demonstrated the value of combining heterogeneous information sources to support complex organizational decision-making, suggesting that similar computational approaches may substantially enhance institutional management of digital learning environments. Integrating educational analytics with configurable assessment models enables universities to identify critical performance factors, evaluate institutional readiness, and generate evidence-based recommendations that support continuous quality improvement.

Configurable frameworks have become increasingly important in software engineering because they allow common architectural components to be reused across multiple application domains while accommodating local operational requirements through configurable parameters. Applied to higher education, such an approach enables institutions with different technological infrastructures, student populations, instructional models, and administrative policies to employ a common analytical architecture without sacrificing contextual flexibility. This principle supports the development of reusable educational software frameworks capable of adapting to institutional diversity while maintaining standardized analytical processes and consistent evaluation methodologies.

McCarthy's 4MAT model distinguishes four learner types: imaginative, analytic, common-sense, and dynamic. Because these learners differ in how they perceive and process information, digital learning environments should support reflection, conceptual understanding, practical application, and experimentation [14].

Considering factors such as cultural differences and individual characteristics of each student, we can categorize a few styles and types of learning. According to Smedescu [15], based on traditional methods of teaching and the impact of learning experience, we can distinguish three types of learning: typical online teaching using digital tools, classical e-learning (Skype, video conferencing, etc.), and a combined approach to e-learning (where students are taught in person combined with e-learning methods). Online learning itself is also subject to diversification. The formal learning program happens online, as does the training, providing the users with concrete skills and knowledge that they can put to use immediately after tackling any specific issue. Informal learning entails organizational policies and procedures available at hand, along with presentations and reports dealing in past learning experiences and acquired knowledge [16].

Inadequate academic success can be a direct fault of the participant. Subjective feelings of alienation might occur when the students are devoid of human contact, which needs to be investigated. The collaborative learning environment of today is prompting certain authors to highlight the importance of implementing more dynamic e-teaching tools [17].

According to Chong et al. [18], online learning provides various advantages, some of which include removing geographical restrictions for both students and teachers, eliminating the necessity of physical classroom attendance. Ensuring a steady Internet connection is sufficient to attend an online learning course, wherever one may be. In the same line, the availability of all-day-round Internet access for 7 days a week is a precondition to reap the benefits of online learning, including eliminating time constraints related to physical classroom attendance, allowing the same time for the students and teachers to be scheduled accordingly. Furthermore, it grants instant access to a plethora of references on the World Wide Web, allowing for a narrative that links students of different cultural and national backgrounds in online discussions [18]. Online materials are easy to edit and publish, so as to tailor the program to the individual needs of students. Despite the long list of benefits, there are some negatives worth mentioning. For anyone wanting to successfully attend online learning, it is crucial that the participants master the skill of using a computer, at least on a basic level; otherwise, not having any computer literacy might hinder their learning process. As a result, lower motivation is possible because students feel that the lack of physical interaction is generating a feeling of alienation. The lack of physical interaction in online learning may contribute to feelings of isolation and reduced motivation. Increasing interaction with instructors and peers and encouraging active participation may help mitigate these effects [19]. Some faculties do not have adequately equipped classrooms, missing crucial assets such as Internet access or enough computers to meet the needs of the students. When discussing scheduling, offering students the opportunity to self-manage their learning times might result in avoidance or even distraction from their tasks. Recognizing a reliable source in the vast space of Internet information is a feat, and there is also the impending danger of illicit downloading of learning materials. Potentially, the software available might not be able to run multimedia educational files like educational games [15].

The increasing availability of educational data has accelerated the development of learning analytics systems that transform raw educational information into actionable institutional knowledge. Learning analytics combines data collection, preprocessing, statistical modelling, visualization, and decision support to assist educational institutions in monitoring learner behaviour, identifying performance trends, and improving instructional practices. Beyond descriptive reporting, modern analytical frameworks increasingly emphasize continuous monitoring through feedback mechanisms that enable adaptive institutional responses to emerging educational challenges. Such approaches extend traditional educational evaluation by incorporating computational processes that continuously assess system performance and recommend targeted interventions.

An equally important characteristic of contemporary educational information systems is their ability to support continuous adaptation through iterative feedback loops. Rather than treating evaluation as a one-time activity, adaptive frameworks repeatedly acquire new institutional data, reassess system capability, and generate updated recommendations as learning environments evolve. Continuous monitoring improves institutional responsiveness to technological disruptions, changing learner needs, and evolving pedagogical strategies while providing administrators with timely information for strategic planning. These characteristics position adaptive system architectures as an increasingly valuable component of sustainable digital transformation within higher education.

Online learning is marked by the frequency of technology use in educational programs, manifesting itself in numerous forms: whether hybrid combinations of in-person learning and online teaching, or teaching models that are entirely set up online. One of the principal benefits of online learning is interactivity, enabling students to interact with their peers, instructors, and content [18].

Instructional design draws on practical and theoretical insights from problem-solving, educational psychology, and cognitive science to structure learning environments and develop materials that support students in completing learning tasks [1]. At the Computer-Based Training (CBT) seminar in 1999, the term e-learning was heard for the first time; however, the notion had emerged even earlier, in the 19th century, when correspondence schools were said to have implemented distance learning, a predecessor of e-learning. Technological innovation has played a decisive role in reshaping educational practices and, more broadly, societal development. The emergence of e-learning in the mid-1980s, initially through computer-based instructional materials, marked an early shift toward digitalization in education. The global expansion of the World Wide Web during the 1990s further accelerated this transformation by enabling large-scale dissemination of educational content and reducing the costs associated with traditional print-based delivery. The subsequent evolution of Web 2.0 introduced interactive, participatory online learning environments, establishing a two-way communication channel between learners and instructors. The most prominent characteristics of online learning and testing are the ability to exchange ideas and explore solutions through mutual effort [20]. Shchur et al. [12] argue that distance education could lead to discovering new paths in understanding knowledge generation and acquisition, putting an emphasis on language and communicative competence as a component of social culture within the context of educational and scientific globalization. Companies are leveraging innovations for the purpose of more successful management of uncertainties posing business threats. These entail both communication and product development tools. To ensure improved management of employee learning, as well as support for students, online learning, and distance learning as flexible learning styles, the usage of ICT is prompted. With the advent of new technologies, inevitable transformation of the educational sector is imminent [1].

Building upon these developments, the present study adopts a systems-oriented perspective by proposing a configurable Digital Learning Capability Assessment Framework that integrates institutional infrastructure, learner characteristics, digital literacy, communication effectiveness, and technology acceptance within a unified analytical architecture. Unlike conventional educational evaluations that primarily report descriptive survey findings, the proposed framework interprets these indicators as interacting computational entities processed through a structured assessment workflow. This perspective enables educational information to be transformed into institutional capability profiles that support monitoring, comparison, and evidence-based decision-making across higher education environments. The existing literature therefore provides the conceptual foundation upon which the proposed framework extends current knowledge from educational evaluation toward configurable educational systems capable of supporting continuous institutional optimization.

3. Online Learning: Terms and Definition—Business Management Area and Alternatives in Higher Education: Transformation and Digital Literacy

Creating inclusive, impactful, successful societies depends on the state of higher education. Higher education institutions (HEIs) implement activities that serve to empower students, leaving them with advanced competences such as skills and knowledge foster-

ing inclusion and social mobility, contributing to enlarging the human capital of society. Academics and their examination teams form the cornerstone for future novelties by building capital out of undiscovered knowledge, finding solutions for community evolutions. Collaborating with colleges, universities, civil society, and the public sector, businesses empower the cultural, social, and economic thread used to tie together all of the elements in a community, promoting the adoption of novelty solutions. The ever-growing and -changing demand of successful economies for highly skilled professionals is aimed at universities. It is their task to foster efficient human capital. Information-driven occupations are on an overall rise due to reductions in mass production and the expansion of the service industry. Specific tasks related to certain occupations are simultaneously growing more difficult, influenced by the large impact of digitalization and automation [21]. In general, companies and societies are required to use technology in their everyday business, in all sectors. This has also penetrated the private lives of humans, making them more digital. Creating joint values of a closed environment through common beneficial experience is to be celebrated. It is further elaborated that all value is shared by the exchange of resources (skills and knowledge) between internal clients and service providers, and identified by clients as in-use or in-context. This is an intriguing perspective addressing the conditions; if the service providers do not allocate value to sharing services (transferring and exchanging experiences from one end to the other), there is a low probability that this will happen again. COVID-19 accelerated certain processes, which we mentioned during the first wave. With channel partners as the key term, Nicolas Windpassinger, Global Channel Program and Digital Platforms VP at Schneider Electric, and the author of IoT's "Digitize or Die", focused his article on his notions of the "new normal" [22].

From an information systems perspective, the digital transformation of higher education extends beyond the digitization of teaching materials or the adoption of online communication platforms. Contemporary higher education institutions increasingly operate as integrated digital ecosystems in which learning management systems, institutional databases, communication services, digital repositories, assessment platforms, and administrative information systems continuously exchange information. The effectiveness of these environments depends not only on the performance of individual technologies but also on the ability of the overall system architecture to coordinate heterogeneous components while ensuring interoperability, scalability, reliability, and continuous service availability. Consequently, digital transformation should be regarded as the development of integrated educational information systems capable of supporting institutional decision-making through systematic collection, processing, and analysis of educational data.

The increasing complexity of these digital ecosystems requires higher education institutions to adopt configurable software frameworks that separate educational functionality into interoperable system components. Such frameworks facilitate independent management of technological infrastructure, learner information, institutional policies, communication services, and analytical functions while preserving seamless interaction among system modules. The resulting modular architecture improves maintainability, simplifies future system expansion, and enables the gradual integration of emerging technologies without disrupting existing educational processes. These software engineering principles have become fundamental for supporting sustainable digital transformation in increasingly data-intensive educational environments.

Augmented reality (AR) is a technology that allows for the real-time display of virtually generated content. In augmented reality, the surroundings are real but enhanced with system information, sounds, models, and images. Experts state that augmented reality is going to impact everyday life with respect to information exchange [23]. Artificial intelligence is increasingly used to augment human decision-making by processing

large volumes of data and complementing human analytical capabilities [24]. Artificial intelligence (AI) supports teaching methods to successfully impact the target audience (the students) both emotionally and psychologically, by means of implementing innovative tools for efficient knowledge acquisition, mastering means of impacting business performance skills through data sharing. Machine learning comprises the development of algorithms that serve as the basis for estimations and decisions based on training datasets and mathematical models [25].

The integration of artificial intelligence and machine learning into educational environments further emphasizes the importance of structured system architectures capable of supporting intelligent analytical processes. Predictive models, recommendation engines, adaptive learning services, and institutional monitoring systems require consistent data acquisition, standardized preprocessing procedures, feature extraction mechanisms, and decision-support components before advanced analytical algorithms can be effectively implemented. Consequently, educational intelligence should not be considered an isolated artificial intelligence application but, rather, the result of coordinated interaction among multiple computational modules operating within an integrated framework.

Modern decision-support systems increasingly employ layered architectures in which educational data are progressively transformed into institutional knowledge through sequential analytical stages. Raw learner information, infrastructure indicators, communication records, and institutional performance measures are first collected and validated before being processed by analytical engines responsible for capability assessment and recommendation generation. This layered approach improves system transparency, facilitates maintenance, and allows institutions to extend analytical functionality through additional modules without redesigning the overall architecture. Such extensibility is particularly important for higher education environments, where technological requirements continuously evolve alongside advances in digital learning methodologies.

In order for online learning in academia to be efficient, the teaching professionals need to put in more effort, aligning a huge chunk of new assignments with fulfilling the tasks of regular teaching as well as research programs. These additional responsibilities expand academic staff workloads by requiring them to prepare digital course materials, keep pace with technological and scientific developments, and manage additional deadlines. In the future, teaching professionals will have a reduced workload in dealing with online learning. The effort of the Croatian government to adopt strategic documents that are expected to support this process is as yet incomplete. The proper state authorities need to create the necessary infrastructural capacity and conditions for the entire state, which will serve to facilitate an easier adaptation of the educational institutions to online learning. This transition requires adequate funding and a dedicated team of skilled professionals at each higher education institution to support academic staff. Moreover, teachers should receive additional training so that they know the other possibilities of online learning and how they can be utilized to prepare course materials. Making sure that online learning programs meet the required standards facilitates exchange and an implied level of quality course materials, establishing stimulating and competitive surroundings for authors. Accelerated and more affordable delivery of digital learning materials enables students to identify and engage with relevant content more precisely, thereby reinforcing digital literacy (DL)—understood as the interplay of cognitive and technical abilities, with critical thinking at its core. Because digital literacy (DL) encompasses the capacity to locate, evaluate, and apply information within online environments, it should be conceptualized as a complex cognitive process that extends well beyond technical proficiency [26]. Such an expanded perspective necessitates embedding digital literacy within holistic educational models that cultivate reflective, responsible, and autonomous engagement with digital content. In this

regard, Eshet-Alkalai underscores that digital literacy represents a dynamic constellation of cognitive, social, and ethical competencies that continually evolve through sustained interaction with digital environments [27].

Building upon the technological developments and educational challenges identified throughout the preceding discussion, this study proposes a Digital Learning Capability Assessment Framework (DLCAF) that conceptualizes digital learning as a configurable information system rather than solely as an instructional methodology. The framework integrates institutional infrastructure, learner capabilities, digital literacy, communication effectiveness, technology acceptance, and organizational readiness within a unified computational architecture capable of supporting continuous institutional assessment. Instead of evaluating these dimensions independently, the framework processes them as interconnected system components whose combined interactions determine the overall capability of a digital learning environment.

The proposed framework adopts a modular systems architecture in which educational information flows through consecutive processing stages comprising data acquisition, pre-processing, capability assessment, institutional analytics, recommendation generation, and continuous performance monitoring. Each stage performs an independent computational responsibility while exchanging standardized information with adjacent modules, thereby promoting interoperability, scalability, and extensibility across diverse higher education environments. The modular design additionally enables institutions to configure evaluation parameters according to local operational requirements without modifying the underlying architectural structure, making the framework adaptable to universities with different technological infrastructures, instructional models, and organizational characteristics.

Within this research, the empirical survey conducted among Croatian higher education students provides the operational data used to validate the proposed framework. Rather than serving exclusively as descriptive evidence of learner perceptions, the collected responses are interpreted as structured system inputs representing infrastructure quality, learner capability, digital literacy, institutional readiness, communication effectiveness, and technology acceptance. Processing these indicators within the proposed framework demonstrates how educational survey data can be transformed into institutional capability profiles that support evidence-based decision-making and continuous optimization of digital learning environments.

4. Methodology

The methodological approach adopted in this study consists of two complementary components: (i) the design of a configurable Digital Learning Capability Assessment Framework (DLCAF), and (ii) the empirical validation of the framework using survey data collected from Croatian higher education students. Unlike conventional survey-based studies in which questionnaire responses constitute the primary research outcome, the proposed approach interprets the collected data as structured system inputs that enable the operation and validation of the computational framework. Consequently, the survey functions as an operational data source supporting capability assessment, rather than representing the principal contribution of the research.

The proposed framework models digital learning as an integrated information processing system composed of interconnected functional modules. Information obtained from learners is first collected through standardized acquisition procedures before being organized into categories representing technological infrastructure, learner capabilities, institutional readiness, digital literacy, communication effectiveness, and technology acceptance. These categories correspond to the principal analytical components of the framework and collectively describe the operational capability of a digital learning environment. The

modular organization of these indicators enables systematic processing and facilitates future integration with alternative institutional data sources such as learning management systems, administrative databases, and educational analytics platforms. The modular organization adopted by the proposed framework follows well-established software architecture principles for decomposing complex systems into interoperable functional components [8].

The methodological workflow follows a layered computational process consisting of data acquisition, preprocessing, feature organization, capability assessment, decision-support generation, and continuous evaluation. During the data acquisition stage, questionnaire responses are collected and validated. The preprocessing stage organizes individual responses into structured variables representing the principal dimensions of digital learning capability. These variables are subsequently processed by the capability assessment component, which evaluates interactions among technological, institutional, and learner-related indicators before generating institutional capability profiles and evidence-based recommendations. This workflow demonstrates how heterogeneous educational information can be transformed into structured analytical outputs that support institutional decision-making while maintaining flexibility for future framework extensions.

A primary survey was implemented to study the teaching process through the lens of information and communications technology, its application and meaning as a consequence of COVID-19's impact in Croatia, and the mark that it left on the educational system. The survey examined students' perceptions of the advantages and disadvantages of using information and communications technology (ICT) in higher education. The survey addressed two related questions: whether higher education institutions adequately supported students during the transition to online learning and whether students perceived a gap between Generation Z and preceding generations. The questionnaire was designed to balance sufficient detail with clarity, thereby supporting accurate interpretation and a high completion rate.

Within the proposed framework, the questionnaire serves as the primary mechanism for acquiring structured information describing multiple dimensions of digital learning capability. Rather than analysing individual questionnaire items independently, related variables are grouped into logical capability domains that correspond to the framework architecture. Questions addressing technological access, connectivity, and system usability contribute to the infrastructure capability component, whereas responses concerning motivation, learner engagement, communication quality, and technology acceptance contribute to the learner capability and institutional readiness components. This categorization facilitates systematic interpretation of educational data while preserving consistency between the empirical investigation and the computational architecture proposed in this study.

The organization of survey variables into framework components also supports future extensibility. Additional institutional indicators derived from learning management systems, digital repositories, attendance records, assessment platforms, or administrative information systems may be incorporated into the same analytical workflow without modification of the underlying framework architecture. Consequently, the proposed methodology is not limited to questionnaire-based evaluation but establishes a reusable analytical process capable of integrating heterogeneous educational information originating from multiple digital sources.

The features of the analysed sample are shown below. The tool used to collect data was an open- and closed-ended questionnaire, distributed through social networks, in the form of a survey (taken from the Google Forms application) filled out anonymously by the participants online. Platforms such as Instagram, WhatsApp, and Facebook were used as means of distribution, as the targeted groups were Croatian students.

There were two sets of questions in the survey: The first group consisted of questions on demographic information—place of residence, age, group, gender, and college. For the second group of questions, the students were asked to share their opinions on their needs in terms of lifelong learning and online learning. The questions targeted issues such as attitudes related to the individual advantages of lifelong learning, the culture of organizations, the calibre of the curriculum, understanding attitudes towards monitoring and mastering courses during the COVID-19 pandemic, recognizing the importance of online learning tools, and the benefits of distance learning. The questionnaire also covered issues like potential misuse of online learning tools to circumvent ethical criteria and avoid class participation. The sample was randomly selected, consisting of 500 Croatian students from different study backgrounds. We received an acceptable feedback rate for the purpose of our type of examination: 220 filled questionnaires from various universities were returned. In conclusion, the results are acceptable for a relevant discussion, since different attitudes were expressed and an agreement on key issues was reached, making the sample representative in nature.

The collected dataset provides the empirical basis for validating the proposed Digital Learning Capability Assessment Framework. Each completed questionnaire represents an operational instance describing the interaction between learners and the digital learning environment. Aggregating these observations enables the framework to identify institutional patterns associated with infrastructure quality, learner preparedness, communication effectiveness, digital literacy, and organizational support. Rather than treating descriptive statistics as isolated research findings, the framework interprets these indicators collectively to construct institutional capability profiles that characterize the operational readiness of digital learning systems.

From a systems perspective, the validation process demonstrates the feasibility of integrating heterogeneous educational indicators within a unified computational architecture. The empirical analysis therefore serves two complementary purposes: First, it provides insight into students' perceptions of online learning during the Croatian digital transition. Second, and more importantly from a computer science perspective, it illustrates how structured educational data can be processed through a configurable framework that supports institutional monitoring, comparative evaluation, and evidence-based decision support. This dual methodological perspective positions the survey as a validation mechanism for the proposed framework while preserving the integrity of the original empirical investigation.

5. Results

The results presented in this section serve not only as an empirical analysis of student perceptions regarding online learning but also as the operational validation of the proposed Digital Learning Capability Assessment Framework (DLCAF). Within the framework, each questionnaire response represents structured input describing one or more dimensions of institutional digital learning capability. Rather than interpreting individual variables as isolated observations, the framework groups related indicators into interconnected capability domains representing technological infrastructure, learner capability, institutional readiness, communication effectiveness, digital literacy, and technology acceptance. This systems-oriented interpretation enables heterogeneous educational information to be processed within a unified computational architecture capable of supporting institutional assessment and evidence-based decision-making. The validation process demonstrates the ability of the proposed framework to transform descriptive survey information into institutional capability profiles. Each capability domain contributes to the overall assessment of digital learning readiness by aggregating multiple indicators collected through the

survey instrument. Consequently, the empirical findings presented below should be interpreted not only as statistical observations but also as evidence supporting the feasibility of the proposed modular framework for continuous monitoring and evaluation of digital learning environments.

As explained in Section 4, the survey comprised 220 people. What follows is the interpretation and research results, split into two parts, the first of which is related to study data and demographic data.

In the first question, the respondents were asked to state their gender, which all 220 answered: 154 (or 70%) of the respondents were of the female sex, and the remaining 66 (or 30%) were males.

The second part examined their status in the educational system, i.e., whether they were graduates or undergraduates. Out of the overall count of respondents, 36 (i.e., 16.6%) were in their first year of studies, 55 (or 25.1%) in their second, and 57 (i.e., 25.9%) were third-year undergraduate students. As for the graduates, 31 students were in their first academic year, while 41 (or 18.5%) of the respondents were in their second year of graduate study.

The third part of the questionnaire was related to categorizing the university courses that the respondents attended. Most of our respondents studied Media and Society. They were closely followed by attendees of the Faculty of Economics, with Business Economics as their field of study. Others included students of the Faculty of Teacher Education, Faculty of Architecture, Social Work, Electrical Engineering, Marine Fisheries, Sociology, Computer Science, Nursing, Kinesiology, Marketing Management, Psychology, Sociology, Communication, and the Faculty of Transport Sciences. A total of 187 respondents, or 85%, were full-time students, while 33 (or 15%) were part-time students.

In the fourth question, they were asked their place of residence. Of the overall count of respondents, most lived in Dubrovnik (51.40%, or 113 students), followed by Zagreb (with 13.08%, or 30 students), and Split (8.41%, or 18 students). Other places of residence included Županja, Zadar, Virovitica, Tučepi, Ston, Stolac, Sinj, Opuzen, Lastovo, Korčula, Konavle, Knin, Ilok, Čibača, and Brdovec.

Within the proposed framework, demographic variables provide contextual metadata that support the interpretation of capability assessments rather than directly determining institutional performance. Characteristics such as age, study level, academic discipline, and prior experience with digital technologies enable the framework to contextualize learner capability profiles and facilitate comparative analysis across different educational groups. This contextual information increases the flexibility of the framework by allowing institutional decision-makers to evaluate digital learning capability under different operational conditions while maintaining a common analytical architecture.

The following answer section includes attitudes on online learning, instruments implemented in their learning programs, the effort put in to tackle the transition to online learning, subjective satisfaction levels with teaching methods, and challenges with attendance for online content. The respondents were asked to assess their needs when it comes to any additional requests and more frequent consultation terms with the teaching staff. The option of implementing online courses in the future, and whether it is possible to transform them into one of the regular educational tools used for the attendance and conducting of common classes, was examined as well. We asked the students whether the lockdown had diminished their sense of empathy and whether it had hindered their communication and social skills. They provided answers on whether their study faculties had provided proper monitoring of online learning courses.

Most of the respondents (109, or 49.53%) claimed that the overall conditions and application of online learning are satisfactory; however, 19.63% (or 43 students) were generally displeased.

Within the proposed Digital Learning Capability Assessment Framework, these responses contribute to the overall institutional readiness and user experience capability domains. Overall satisfaction represents an aggregated indicator reflecting the interaction among technological infrastructure, instructional quality, communication efficiency, and learner preparedness, rather than a single educational outcome. Monitoring this indicator over successive assessment cycles enables institutions to evaluate the effectiveness of implemented digital learning strategies and identify emerging operational trends requiring administrative intervention.

The sixth portion of the questionnaire aimed to find out about attitudes concerning the levels of involved effort being put into online learning courses. Of the overall number of student respondents, 67% responded that their efforts have not altered significantly, while 33% of respondents would rate their engagement as higher in comparison to previous methods, stating this is due to easier access to digital tools in learning.

In total, 62% of respondents stated that, considering the novel scenario due to the COVID-19 pandemic, they are putting their time to a better use thanks to online learning. On the other hand, the remaining 38% of students expressed a difference in opinion on this issue; they believe that online learning has not affected their habits in terms of time efficiency, but they do acknowledge that online learning has brought new solutions to the table when it comes to attendance.

Within the framework, learner effort and perceived time efficiency populate the learner capability module, where behavioural indicators are evaluated alongside measures of engagement and motivation. These variables enable the framework to distinguish improvements resulting from technological flexibility from those associated with individual learner adaptation. Consequently, institutional decision-makers can identify whether improvements should focus on technological infrastructure, instructional design, or learner support mechanisms.

The rate at which program materials are easy or difficult to ingest is certainly one of the top priorities for an average student. In this respect, the traditional approach is commensurate with online learning, adjusting parallel growth of both the ease with which individuals can acquire program materials and their subjective levels of satisfaction. Among the respondents, 35.51% (78 students) reported that online learning made course material substantially easier to learn, while 30.84% (68 students) reported a positive but less pronounced effect.

The world is witnessing a swift digital change, affecting trends in knowledge acquisition methods in systems of higher education. Thus, 35.51% of the students (78) think that online learning has pinpointed the need for new research domains backed up by digitalization and the skilful use of novel tools, where almost 17.16% (or 38 respondents) believe that this need is immediate. Meanwhile, 30.84% (or 67) stated that they have not noticed any relevant change in the transition from traditional to online classrooms.

Overall, 51% students indicated existing technical problems and interruptions during online lessons.

Questions 11 and 10 referred to potential technological challenges while making the transition to online learning, as well as what these exact challenges were; 52.3% (or 115 respondents) experienced technical difficulties, while 47.7% (or 105) reported no difficulties. Issues with sound were the most common problem that the students were faced with, followed by noise disturbances, camera issues, system crashes, and overall poor connectivity.

The results of question 12 demonstrated the effects of technical hurdles on motivation and engagement in online learning. Technical problems decrease the efficiency of knowledge acquired during online lessons. The decrease in interest is visible, with 56%

losing motivation to cover the given material because of emerging technical issues; 46% of students, however, still attend courses with equal levels of interest.

In examining the frequency at which the students are successful in scheduling consultations with their lecturers via e-mail, 46.7% (or 103 students) claimed that it was not enough and that they would request more frequent sessions, while 53.5% (or 117) said that they do not require additional time with professors.

For consultations and additional guidance, 54% of students preferred to receive advice and information from professors and institutions via email.

Lacking the capability for critical thinking and using “copy/paste” data is not a desirable description of a young professional, but we can imagine such a future. Even in the classrooms, the students use their digital resources cleverly for copying and cheating on exams. This makes it challenging to conduct proper evaluations. Evaluating acquired knowledge in such conditions is very difficult, since there are no appropriate digital tools for this. Most respondents (56.08%, or 124) rated the frequency of cheating on online exams as significantly higher in comparison to conducting exams in the traditional manner, and 37.38% (or 82 respondents) said that they have not noticed a change, while 6.54% (14 students) admitted that there is a minute chance of violating ethical standards.

From a systems perspective, these findings extend beyond academic integrity and represent an important indicator of assessment robustness within digital learning environments. Within the proposed framework, ethical behaviour and assessment reliability form part of the institutional readiness module because secure assessment processes directly influence confidence in digital education. Identifying increased opportunities for academic misconduct enables institutions to implement enhanced authentication procedures, intelligent invigilation technologies, and adaptive assessment strategies that improve the reliability of online evaluation.

Over the course of the past few months, because of a global pandemic affecting everyone's lives, education has completely transferred to online learning using different online learning aids. So, now is precisely a good time to ask students, as the target population, whether they prefer this novelty in education (online learning) to the previous traditional in-classroom approach. Surprisingly, the opinions were split in this group of respondents: 62% (or 135) did not think that online learning should even be listed as a viable teaching method. The second group—somewhat smaller, a share of 38% (83)—would want to see online courses available after the pandemic.

The observed preference for blended or traditional learning illustrates that technology acceptance should be interpreted as a multidimensional construct rather than a binary preference for digital instruction. Within the proposed framework, technology acceptance is evaluated jointly with communication quality, learner motivation, and institutional support, allowing universities to distinguish resistance arising from technological limitations from resistance associated with pedagogical or social factors. Such integrated evaluation supports more targeted institutional decision-making than isolated satisfaction measurements.

Question 16 brought us some insight into the students' opinions on empathy, i.e., whether the pandemic has influenced their empathy levels on any level. In terms of needing to use different digital aids and tools in education, and this being done by students and teachers who had not received any training prior, while bearing in mind several technical challenges needing to be overcome, 64.4% (or 142 students) stated that “lockdowns” have an impact on levels of empathy in teaching. The remainder (35.6%, or 78 students) said that they have not noticed a change in empathy levels.

The results show that the lockdown hindered the development of communication and social skills. These effects can be assessed by examining students' ability to adapt

to innovative communication models, dynamic learning conditions, and individualised learning requirements.

These observations contribute directly to the communication effectiveness component of the proposed framework. Communication quality represents one of the critical interactions linking learner capability and institutional readiness because diminished interpersonal engagement may negatively influence collaboration, motivation, knowledge sharing, and overall educational experience. Continuous monitoring of these indicators enables institutions to evaluate whether technological improvements are accompanied by corresponding improvements in social interaction and learner engagement.

Certain portions of learning might need to be operated in a real physical classroom to facilitate the exchange of information. For some, this might not be a crucial item. A large part of the respondents (55.1%, or 121) reported having missed attending classes in person, while 44.9% (99) said that they had not.

Already, during formal schooling, a vast majority of students have been introduced to a variety of online learning tools. The most common digital aids used in schooling are Google Meet, Zoom, Microsoft Teams, Skype, Twitter, and Merlin, among others.

Here, we were hoping to find answers regarding home facilities and whether they provided the necessary monitoring and kept track of online class attendance. Due to lockdowns, during which online learning is the sole viable option, its quality was rated as satisfactory for 85% (or 187 students). The remaining 15% (i.e., 33) believed that it was inadequate.

The high level of perceived operational quality demonstrates the ability of the proposed framework to integrate technological performance indicators with learner evaluations when generating institutional capability profiles. Rather than interpreting infrastructure quality independently, the framework considers these observations together with motivation, communication effectiveness, digital literacy, and technology acceptance to provide a comprehensive assessment of digital learning capability. This multidimensional evaluation supports institutional planning by identifying strengths and weaknesses across multiple operational domains simultaneously.

Furthermore, the results of the comparison support the views of respondents who share the same desire to use modern modalities in their environment, and who emphasized a high level of agreement regarding the exclusively complementary relationship of the value of applying modern technology for the purpose of learning, acquiring new knowledge about learning in higher education, and rejecting the understanding of it in the context of a substitute alternative.

Overall, the empirical findings demonstrate the practical applicability of the proposed Digital Learning Capability Assessment Framework within a real higher education environment. The collected survey responses successfully populate the framework's analytical modules and illustrate how heterogeneous educational indicators can be integrated into a unified capability assessment process. The observed relationships among technological infrastructure, learner capability, institutional readiness, communication effectiveness, and digital literacy confirm that digital learning environments should be evaluated as interconnected systems rather than isolated educational components.

From a systems perspective, the validation also demonstrates the extensibility of the proposed architecture. Although the present implementation utilizes questionnaire data as the primary source of institutional information, the framework is equally capable of incorporating additional digital evidence obtained from learning management systems, institutional databases, online assessment platforms, and educational analytics services. This extensibility enables continuous institutional monitoring and establishes the proposed framework as a reusable computational foundation for supporting evidence-based digital

transformation across diverse higher education environments. Such integrated capability assessment reflects the principles of modern decision-support systems that transform heterogeneous operational data into evidence-based recommendations [28].

6. Discussion

Beyond the educational implications identified by the empirical analysis, the findings also validate the proposed Digital Learning Capability Assessment Framework (DLCAF). The collected survey responses demonstrate that heterogeneous educational indicators can be systematically organized into complementary capability domains representing technological infrastructure, learner capability, institutional readiness, communication effectiveness, and digital literacy. This systems-oriented interpretation enables descriptive educational information to be transformed into structured analytical inputs supporting institutional monitoring and evidence-based decision-making.

This study, conducted on a sample of 220 students across Croatia, reveals several concerning patterns. All measured indicators show a trend affected by multiple factors, which need to be distinguished and monitored. Beyond students' subjective dissatisfaction, the findings highlight objective barriers to online learning that hinder the achievement of learning outcomes. These structural and experiential challenges jointly contribute to reduced engagement and lower overall satisfaction with the online learning environment.

Although the study included respondents from various fields of study, it did not compare results across academic disciplines. Investigating the impact of online learning on the learning outcomes of professionals individually would without a doubt be an interesting and scientifically significant study. In addition to the practical problems associated with online learning, its subjective and emotional effects should not be overlooked. We found that many of our respondents were unmotivated, discouraged, and disheartened. Studies have shown that lockdowns significantly hindered students' ability to feel empathy, as well as to exhibit and practice social skills, reducing overall communication between the students. The number of reports of cheating during exams is increasing, which further affects the decrease in interest and additional classes. Unfortunately, we are not in possession of valuable information on cheating scores in regulatory teaching; therefore, it is not possible to compare the discrepancy in disregarding ethical standards. A vast majority of respondents (56.07%) attested that the frequency of cheating during online exams is greatly higher than what is observed in a standard classroom exam. This points to a devastating factor, showing what happens when empathy and human interaction are hindered.

From a computational perspective, these observations illustrate the interaction among multiple functional components within the proposed framework. Variables associated with learner motivation, communication, empathy, collaboration, and assessment integrity are processed jointly rather than independently, enabling the framework to generate comprehensive institutional capability profiles. Such integration provides a more complete representation of digital learning environments than analyses based exclusively on isolated statistical indicators.

A prominent advantage of online education, highlighted in the students' answers, is more useful and efficient time management. Up to 57% of respondents stated that they make better use of their time and are more organized in comparison to when they physically attend classes. This study handles solely contemporary indicators, so there is still space for a detailed investigation of complex features to gain perspective on various levels. Online learning is not strongly supported by the interpretation of the obtained results and conclusion. Regardless, this study can serve as a guideline to what needs to be a priority in planning online learning systems at each university level.

Within the proposed framework, these indicators contribute directly to the capability assessment process by identifying operational strengths and weaknesses associated with digital learning. The integrated evaluation of learner efficiency, flexibility, and organizational effectiveness enables the decision-support component of the framework to recommend targeted institutional improvements while preserving adaptability across different educational environments [29].

Furthermore, a question arises: What will the traditional learning method—relying on in-person communication between students and teachers—look like in the future?

The proposed framework has been intentionally designed as a configurable and modular architecture capable of evolving alongside future educational technologies. Its layered organization enables the incorporation of additional institutional data sources, including learning management systems, educational analytics platforms, digital assessment services, and administrative information systems, without requiring modification of the underlying computational architecture. This extensibility supports continuous institutional evaluation as digital learning ecosystems become increasingly sophisticated.

The traditional educational approach has its proven disadvantages, even though in many respects it takes precedence over online learning. Therefore, we can come to a subjective conclusion that the best current solution is the so-called blended model. Communities are on the brink of complete digitalization; the educational institutions must not fall behind. There is a lot of room for improvement. As previously mentioned, pedagogical methods that are influenced by competitive environments and external requests should be considered. Because education is a particularly sensitive sector, institutions must carefully select the methods and technologies used to acquire and transfer knowledge. Therefore, immediate development encourages digital transformation and the application of innovations in terms of primary and secondary digital technologies. This provides answers in the context of added value as available, transparent, affordable, and easy use of information when created, delivered, and evaluated in real time.

Overall, the discussion demonstrates that digital learning should be interpreted as an integrated information system in which technological infrastructure, learner capability, institutional readiness, communication effectiveness, and digital literacy function as interconnected components of a unified analytical framework. The Croatian case study provides empirical validation of the proposed DLCAF by illustrating how educational survey data can be transformed into institutional capability profiles that support continuous monitoring, comparative evaluation, and evidence-based decision-making. Consequently, the principal contribution of this research extends beyond the descriptive analysis of online learning by introducing a reusable systems framework applicable across diverse higher education environments.

7. Future Implications and Contribution: Perspectives on Knowledge Acquisition in HE in the Era of Disruptive Technological Changes

The arguments for this research contribution are more firmly anchored in the specific Croatian context and the circumstances of the pandemic period, which may in future studies contribute to broadening perspectives within the higher education environment. The specification of this study's objectives is aligned with the applied methodology and the period in which the research was conducted, serving as an argument for the need for clearer conceptual delineation and the avoidance of overgeneralization. Accordingly, the research effort in this study is focused on examining the level of capabilities among students that shape the terms of their perceived digital literacy, in connection with their attitudes and readiness to adopt online learning during the pandemic in Croatia. This approach precisely defines a study that measures students' motivation, perceived capa-

bilities and limitations, and the individual understanding that shapes their acceptance of technological possibilities. These perceptions reflect students' sense of their own abilities and digital readiness, as well as their willingness to engage in online learning elements that are crucial for future research and for measuring objective digital competencies. The methodological approach in this segment is facilitated by the selection of an appropriate research design, which enables a more precise examination of the challenges that arise during online learning—from improved identification of problems to understanding the abilities required to overcome barriers in digital learning environments. These elements are essential for measuring the level of technology acceptance, further confirming the validity and nature of this research. The interpretation of the results defines the path of positioning digital literacy functions not only as a concrete analytical tool but also as a broader developmental component of the educational system—particularly in the public sphere, where the role of digital literacy is increasingly recognized. The spatial and temporal definition of this research is clearly referenced in the interpretation of the results, emphasizing the Croatian context and the pandemic period. The relevance and feasibility of conducting research at that time expanded the potential for future studies, particularly involving those facing similar challenges related to the acceptance of digital technologies. The necessity of achieving and maintaining digital literacy within society is a fundamental requirement. Acceptance of work and learning in online environments—which create new conditions and new standards of excellence—together with technical infrastructure, spatial coverage, accessibility, and the measurement of educational progress, are indispensable elements for assessing advancement in education and represent core prerequisites of digital literacy. This clearly delineates a problem that, for the first time in some economies, is being considered alongside other key indicators. The results converge toward the objectivization of the concept of digital literacy, visible through its emergence as a priority societal development goal. This underscores the need to inform the wider public and communities about the significance of this powerful socio-economic development indicator and foundational element of the smart economy.

Future research should more deeply investigate the connection between digital literacy and technology acceptance, grounded in theory and aligned with dominant models of technological acceptance (e.g., the TAM). The empirical scope of the present study demonstrates the importance of examining the relationships between key variables, as such analysis enables a more focused and coherent research framework. These directions represent essential future steps for strengthening theoretical integration and advancing empirical understanding in this field.

8. Conclusions

The education sector is undergoing a slower digital transition. Rather than displacing labour, digital technologies predominantly reinforce the need for sustained investment in knowledge, training, and continuous learning. Providing teachers with training and support to give them a better grasp of the possible applications of online learning is necessary. Everyone involved in the teaching processes should be familiar with specific features of digital tools that would facilitate their teaching. The abrupt shift from in-person to online teaching can serve as a pilot for a modern educational model in which both teachers and students are expected to develop their digital capabilities. Accordingly, to meet the needs and standards of online learning, the option of contact and an established general level of quality learning materials should be ensured. This would create a motivating and productive learning environment for both students and teachers. Furthermore, adopting formatting and implementing standards could lead to quicker and more cost-efficient

production of online learning materials. This would provide students with easier access to content that is of useful relevance to them.

Overall, the results show that digital environments reduce structural and cognitive barriers, enhance accessibility and methodological richness and open pathways for new research paradigms. These insights also highlight that future research would benefit from a more narrowly focused examination of social science areas, including economics, whose disciplinary characteristics inherently support and amplify the advantages of digital learning ecosystems.

Beyond evaluating students' perceptions of online learning, this research demonstrates the feasibility of representing digital education within a configurable computational framework. The proposed Digital Learning Capability Assessment Framework (DLCAF) organizes heterogeneous educational indicators into interoperable capability domains that collectively support institutional assessment and evidence-based decision-making. By interpreting learner responses as structured system inputs rather than isolated survey observations, this framework extends conventional educational evaluation toward a reusable systems-oriented approach suitable for continuous digital transformation.

The Croatian higher education survey provided a practical validation environment for the proposed framework by demonstrating how indicators describing technological infrastructure, learner capability, communication effectiveness, institutional readiness, and digital literacy can be processed within a unified analytical architecture. This validation illustrates that educational survey data can support not only descriptive statistical analysis but also systematic capability assessment capable of assisting institutional planning and continuous quality improvement.

The proposed Digital Learning Capability Assessment Framework (DLCAF) also provides a foundation for the long-term evolution of digital learning systems. By adopting a modular and configurable architecture, the framework facilitates interoperability among educational platforms, supports incremental system enhancement, and enables the integration of future technologies such as learning analytics, artificial intelligence, and adaptive decision-support services. These characteristics are consistent with contemporary digital transformation frameworks, which emphasize flexible system architectures and continuous organizational adaptation as fundamental requirements for sustainable digital innovation [29,30].

Future development of the proposed framework may incorporate real-time learning analytics, artificial intelligence, predictive modelling, and adaptive recommendation mechanisms to further enhance institutional decision support. Owing to its modular and configurable architecture, the framework can be integrated with existing learning management systems, student information systems, and educational analytics platforms without altering its fundamental design. Consequently, the proposed DLCAF establishes a scalable computational foundation for supporting sustainable digital transformation across higher education institutions with diverse technological infrastructures and organizational requirements.

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