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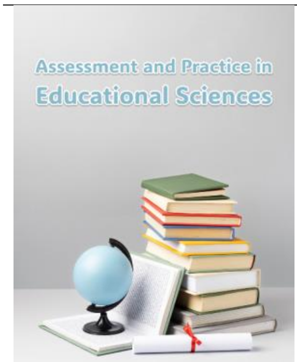

Developing and Validating an Educational System Model for the Literacies Required for Life in the Digital Age among Students of Islamic Azad Universities in Mazandaran Province

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ABSTRACT

This study aimed to develop and validate an integrated educational system model for the literacies required for life in the digital age among students of Islamic Azad Universities in Mazandaran Province. This applied, cross-sectional study used an exploratory mixed-methods design. In the qualitative phase, grounded theory and inductive content analysis were employed. Thirteen experts in digital literacy, educational technology, educational management, and related fields were selected purposively from a population of 20 experts until theoretical saturation was reached. Semi-structured interviews were analyzed using MAXQDA 22. In the quantitative phase, 381 students were selected from a population of approximately 39,000 students through multistage cluster random sampling. A researcher-made 53-item questionnaire assessed 14 dimensions derived from the qualitative phase. Face and content validity were confirmed by experts, convergent validity was evaluated using AVE, and reliability was assessed through Cronbach's alpha and composite reliability. Data were analyzed using SPSS 27 and PLS-SEM. The structural model showed that the effective educational system significantly predicted overall digital-age literacies ($\beta = .478$, $t = 11.775$, $p < .001$). The digital-age literacy construct significantly predicted technological literacy ($\beta = .734$), information literacy ($\beta = .827$), media literacy ($\beta = .835$), digital communication literacy ($\beta = .790$), digital security and ethics literacy ($\beta = .763$), critical thinking/problem-solving/technological innovation ($\beta = .808$), and lifelong learning/digital cultural awareness ($\beta = .803$), all $p < .001$. The educational-system construct significantly predicted curriculum and educational content ($\beta = .890$), policies and strategies ($\beta = .885$), digital-learning culture and values ($\beta = .854$), learner support ($\beta = .814$), teaching and learning methods ($\beta = .774$), technological infrastructure ($\beta = .754$), and faculty competencies and attitudes ($\beta = .749$), all $p < .001$. R^2 values ranged from .459 to .793, all Q^2 values were positive, and SRMR values of .085 and .088 indicated acceptable model fit. The validated model indicates that digital-age literacy development depends on the coordinated interaction of student competencies with curriculum, policy, pedagogy, infrastructure, faculty capability, learner support, and digital-learning culture.

Keywords: Digital Literacy, Educational System, Digital Education, Higher Education, Digital Competence, PLS-SEM, Islamic Azad University

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Introduction

The rapid expansion of digital technologies has transformed the conditions under which individuals learn, communicate, work, access information, participate in society, and make decisions. Digital environments are no longer supplementary spaces that merely support conventional educational and professional activities; rather, they increasingly constitute the primary infrastructure through which knowledge is produced, distributed, evaluated, and applied. The widespread use of learning management systems, social media, cloud-based services, artificial intelligence, digital libraries, virtual classrooms, online collaboration platforms, and mobile technologies has created new opportunities for access to knowledge while simultaneously introducing new requirements for effective participation. Within this context, literacy can no longer be restricted to conventional reading, writing, and numeracy. Contemporary students must acquire a multidimensional set of competencies that enables them to interact with technological systems, critically evaluate information, communicate appropriately in digital environments, create and interpret media content, protect themselves against digital risks, solve complex problems, and continually update their knowledge as technologies evolve. Accordingly, digital literacy has increasingly been conceptualized as a broad educational construct encompassing technological, cognitive, informational, communicative, ethical, cultural, and creative capacities rather than merely the ability to operate digital devices (1, 2).

The significance of these competencies is particularly evident in higher education. Universities are responsible not only for transmitting disciplinary knowledge but also for preparing students for rapidly changing social, professional, and technological environments. The contemporary graduate is expected to search for and evaluate scientific information, use digital tools for academic and professional purposes, collaborate through virtual platforms, produce digital content, understand privacy and cybersecurity risks, communicate across cultural boundaries, use emerging technologies responsibly, and maintain the capacity for continuous self-directed learning. These expectations have made digital literacy an integral component of educational quality and graduate readiness. Recent reviews indicate that digital literacy has become a major area of educational research, with increasing attention being directed toward the interaction between technical skills, information evaluation, educational technology, critical thinking, ethical behavior, and participation in digitally mediated societies (2, 3). Thus, the challenge for higher education is no longer simply to provide students with access to technology but to create educational systems through which they can develop the knowledge, skills, attitudes, and values required to use technology purposefully and responsibly.

This distinction between access to technology and meaningful digital competence is fundamental. Students may use smartphones, social networking platforms, search engines, and online applications extensively without necessarily possessing the competencies required for academically rigorous and ethically responsible digital participation. Frequent technology use does not automatically translate into the ability to distinguish reliable information from misinformation, evaluate the authority of sources, protect personal information, communicate professionally, create meaningful digital content, or critically examine the social consequences of technological practices. Research on digital literacy therefore increasingly emphasizes the quality and intentionality of technology use rather than simple exposure or frequency of use (1, 4). From this perspective, digital literacy involves the capacity to transform access into effective learning, informed decision-making, productive interaction, and responsible participation.

One of the foundational components of digital-age competence is technological literacy. This dimension includes the ability to operate hardware and software, use digital platforms, manage files and data, work with cloud-based services, troubleshoot routine technological problems, and adapt to emerging applications. Yet technological skill alone is insufficient. Students must also possess information literacy, which enables them to identify their information needs, formulate effective search strategies, access reliable scientific resources, evaluate source credibility, synthesize information from multiple sources, and apply information appropriately in academic and professional settings. The growing volume and speed of digital information have made these abilities increasingly important because students frequently encounter information of varying quality, credibility, and ideological orientation. In this environment, critical evaluation becomes a prerequisite for meaningful learning and responsible knowledge production (1, 2).

Media literacy constitutes another essential component of life in the digital age. Digital media environments expose students to a continuous flow of messages, images, videos, advertisements, opinions, and algorithmically curated content. Effective participation therefore requires more than technical access; students must understand how media messages are constructed, recognize persuasive or misleading strategies, assess the credibility of digital content, and identify the social and cultural implications of media representations. At the same time, students are increasingly expected to become producers of digital content rather than passive recipients. Educational activities may require the creation of presentations, podcasts, videos, visual materials, interactive content, and multimedia projects. Consequently, digital media literacy encompasses both critical interpretation and competent, ethical content production. The integration of media literacy into virtual education has been identified as particularly important for improving the quality of technology-mediated learning and strengthening learners' capacity to interact critically with online educational content (5). In addition, interventions directed toward citizenship education have demonstrated the importance of digital and media competencies for shaping more responsible forms of participation and behavior in digital environments (6).

Digital communication literacy is equally important because academic and professional interactions increasingly occur through email, messaging applications, learning management systems, video conferencing, online discussion forums, collaborative workspaces, and professional networks. Effective digital communication requires clarity, appropriate tone, professional etiquette, responsiveness, respect for cultural differences, and awareness of digital identity. Students must understand that online communication creates persistent records and contributes to their academic and professional reputation. Communication competence in digital environments therefore includes not only the technical capacity to use platforms but also the ability to manage relationships, collaborate effectively, participate constructively in groups, and maintain appropriate boundaries. These abilities are especially relevant in universities where collaborative learning, virtual teamwork, hybrid instruction, and online research networks have become increasingly common.

The expansion of digital participation has also increased the importance of security and ethics. Students routinely store personal and academic data online, use cloud applications, participate in social networks, access institutional platforms, and share digital resources. These practices expose them to risks including phishing, identity theft, malware, unauthorized data access, privacy violations, misinformation, and inappropriate use of intellectual property. Digital literacy must therefore include knowledge of strong authentication practices, privacy management, cybersecurity awareness, and safe information-sharing behavior. At the same time, ethical considerations such as respect for copyright, academic integrity, responsible content sharing, protection of others' privacy, respectful communication, and accountability for digital actions are central to responsible participation. The role of security perceptions in technology-related experiences further demonstrates that digital environments must be both usable and trustworthy if users are to engage with them confidently and sustainably (7). Thus, security and ethics are not peripheral concerns but core dimensions of competent digital citizenship.

Beyond operational and behavioral competencies, the digital age requires critical thinking, problem-solving, and technological innovation. The complexity of contemporary digital environments means that students must be able to assess competing claims, interpret evidence, identify underlying assumptions, evaluate the consequences of technological choices, and select appropriate digital tools for solving academic and real-world problems. Critical thinking is particularly important in environments characterized by misinformation, algorithmic recommendations, generative artificial intelligence, and rapidly circulating content. Educational approaches that combine technology with active problem-solving can strengthen both digital literacy and higher-order thinking. For example, problem-based and flipped-learning approaches have been associated with improvements in digital literacy and critical thinking, suggesting that digital competencies are most effectively developed when students are required to actively investigate problems, apply technological resources, collaborate, and reflect on their learning processes (8). Accordingly, digital literacy education should move beyond procedural instruction toward pedagogies that cultivate analytical judgment, creativity, and innovation.

The rapid development of artificial intelligence further intensifies these educational requirements. Generative AI, intelligent tutoring systems, recommendation algorithms, automated writing tools, and conversational agents are changing the ways in which students access information and complete academic tasks. These technologies can facilitate learning, but uncritical dependence may weaken independent judgment, source evaluation, and self-regulated learning. Digital literacy therefore increasingly includes the ability to understand the capabilities and limitations of AI, use it strategically, verify AI-generated outputs, recognize ethical issues, and maintain appropriate human oversight. Recent evidence suggests that digital-literacy education can reduce problematic dependence on chatbots by strengthening users' critical and reflective engagement with AI systems (9). Likewise, research examining teachers' intentions to learn artificial intelligence indicates that digital literacy is closely related to readiness to engage with emerging AI technologies and may operate through actual AI use as an intermediary mechanism (10). These findings suggest that the meaning of digital literacy must remain dynamic and responsive to evolving technological environments.

Another central characteristic of digital competence is lifelong learning. The technologies relevant to today's students may change substantially within a few years, meaning that education cannot simply train students to use a fixed set of applications. Instead, universities must cultivate the capacity and motivation to continuously learn new digital tools, participate in online courses and professional communities, adapt to changing information environments, and update competencies throughout one's career. Lifelong digital learning is therefore both a skill and an orientation toward ongoing professional development. A human-centered perspective on educational technology emphasizes that meaningful integration of digital tools should support learners' interests, agency, engagement, and continuing development rather than treating technology as an end in itself (3). Cultural awareness is also relevant because digital spaces connect users across linguistic, social, and cultural boundaries. Respect for diversity, appropriate intercultural communication, awareness of differing norms, and the ability to participate constructively in global digital environments are increasingly necessary for university graduates.

Although student competencies constitute one side of digital transformation, the educational system itself constitutes the other. Digital literacy cannot be developed sustainably if it is treated merely as an individual responsibility. Universities must provide institutional conditions that enable students to acquire and practice these competencies. These conditions include coherent policies, adequate infrastructure, digital-oriented curricula, innovative pedagogical methods, competent faculty members, learner support, and an organizational culture that values responsible use of technology. Research on e-learning has demonstrated that digital literacy is closely related to successful engagement with technology-mediated learning environments, while organizational and contextual factors can strengthen or weaken this relationship (4, 11). Therefore, an effective educational model must integrate individual competencies with institutional structures and processes.

Educational policies and strategies provide the macro-level framework for this integration. Without explicit institutional priorities, digital transformation may remain fragmented across faculties, courses, or individual instructors. Universities require clear objectives for digital-literacy development, resource allocation, infrastructure improvement, faculty development, curriculum reform, evaluation, and student support. Institutional commitment is especially important because technology adoption depends not only on availability but also on perceived usefulness, perceived ease of use, and users' willingness to engage with technological systems. Technology-acceptance perspectives emphasize that users' beliefs and perceptions play a crucial role in determining whether digital systems become meaningfully embedded in practice (12). In educational settings, these principles imply that successful digital transformation must attend simultaneously to technical quality, usability, perceived value, training, and organizational support.

Curriculum design is another major determinant of students' digital competence. If digital literacy remains external to formal course structures, it may be learned unevenly or left to students' personal experience. Systematic integration requires curricula that incorporate information searching, media analysis, digital communication, cybersecurity, ethical technology use, digital-content production, critical evaluation, and problem-solving within disciplinary learning. Such curricula should also be updated regularly to reflect emerging technologies and labor-market requirements. Digital literacy is especially meaningful when students apply it to authentic disciplinary and professional tasks rather than encountering it only in isolated introductory courses. Consequently, curriculum reform should connect digital competencies to project work, research activities, collaborative assignments, professional scenarios, and assessment practices.

Teaching methods are equally consequential. Technology-rich education does not automatically result in technology-enhanced learning. If conventional teacher-centered instruction is merely transferred to digital platforms, opportunities for interaction, autonomy, collaboration, and critical inquiry may remain limited. Research on teachers' digital literacy indicates that higher levels of digital competence can contribute to the development of teaching skills and more effective use of digital educational environments (13). Similarly, teachers' digital literacy has been associated with their perceptions of the usability and effectiveness of educational networks, indicating that confidence and competence influence how educators engage with digital teaching platforms (14). These findings reinforce the need for pedagogies such as blended learning, flipped instruction, problem-based learning, collaborative projects, interactive platforms, and formative digital assessment.

Faculty competence is therefore a decisive element of the digital educational system. University instructors must possess not only operational technological skills but also pedagogical knowledge about when, why, and how to integrate technology into teaching. A systematic review of digital competence in higher education has shown that teachers' competencies encompass multiple domains, including technical, pedagogical, informational, communicative, and professional dimensions (15). Qualitative research has similarly emphasized that faculty digital competence includes a combination of knowledge, skills, attitudes, and capabilities necessary to effectively integrate digital technologies into academic work (16). Consequently, professional development should extend beyond software training to include digital instructional design, online interaction, multimedia production, digital assessment, data ethics, copyright, and facilitation of student-centered learning.

Infrastructure and learner support constitute further prerequisites. Reliable Internet access, learning management systems, digital libraries, appropriate software, smart classrooms, secure networks, technical services, and accessible support mechanisms all influence students' capacity to participate in digital learning. Organizational support has been identified as an important contributor to e-learning performance and continued engagement with digital learning systems (11). When students encounter unresolved technical problems, inadequate access, or poorly designed digital systems, even strong personal motivation may not translate into effective learning. Conversely, accessible technical assistance, orientation programs, digital-skills workshops, consultation, and supportive institutional policies can reduce barriers and strengthen students' confidence and persistence.

Finally, successful digital education requires an institutional culture that supports responsible experimentation, innovation, ethical conduct, collaboration, and continuous learning. Digital transformation should therefore be understood as a cultural and organizational process, not merely a technological upgrade. Universities need to create environments in which faculty members are encouraged to innovate, students are supported in developing technology-based projects, ethical norms are explicitly promoted, and digital citizenship is incorporated into institutional values. The relationship between digital literacy, educational performance, technology acceptance, and sustainable use indicates that effective digital education emerges from the interaction of individual capability, institutional support, pedagogical design, and user experience (4, 7, 12).

Despite the growing body of research, important gaps remain. Much of the existing literature examines individual dimensions of digital literacy, teacher competencies, e-learning performance, media literacy, technology acceptance, or particular instructional approaches separately. Studies have investigated digital-literacy dimensions among school students (1), teacher and faculty competencies (15, 16), digital literacy and teaching skills (13), digital literacy and educational-network usability (14), media literacy in virtual education (5), citizenship and digital behavior (6), e-learning performance and technology acceptance (4, 11), digital literacy in AI-related learning (9, 10), and instructional models for enhancing digital literacy and critical thinking (8). However, fewer studies have attempted to integrate the required student literacies with the institutional educational-system conditions necessary for their development within a single empirically validated model.

This gap is particularly relevant in the context of higher education in Iran, where universities must simultaneously respond to rapid technological change, increasing use of virtual and blended education, expansion of digital scholarly resources, changing student expectations, and the emerging influence of artificial intelligence. Islamic Azad University represents one of the country's largest higher-education systems, encompassing universities with differing geographical, technological, organizational, and student characteristics. Within Mazandaran Province, the development of an educational system responsive to digital-age requirements requires a context-sensitive understanding of both the literacies students need and the institutional mechanisms through which those literacies can be cultivated. A model developed directly from the experiences of experts and subsequently validated among students can therefore provide a more locally relevant and practically applicable framework than relying exclusively on models developed in different educational or cultural contexts.

Accordingly, a comprehensive educational-system model should distinguish between two interrelated levels. The first is the content level, encompassing technological literacy, information and research literacy, media literacy and content production, digital communication literacy, digital security and ethics literacy, critical thinking/problem-solving/technological innovation, and lifelong learning with digital cultural awareness. The second is the system level, encompassing digital educational policies and strategies, digital-oriented curricula, innovative teaching and learning methods, technological infrastructure, faculty competencies and attitudes, educational and technical support for learners, and the culture and values of digital learning. Examining these two levels together allows digital literacy to be conceptualized not merely as a set of student attributes but as an educational outcome produced through the interaction of learners with curriculum, pedagogy, faculty, infrastructure, support systems, policies, and organizational culture. Such an integrated approach is consistent with contemporary evidence emphasizing the multidimensional, contextual, and human-centered nature of digital competence and educational technology (2, 3).

Therefore, the aim of this study was to develop and validate an integrated educational system model for the literacies required for life in the digital age among students of Islamic Azad Universities in Mazandaran Province.

Methods and Materials

Study Design and Particiapnts

The present study was applied in terms of its purpose, employed an exploratory mixed-methods approach in terms of the nature of the data, and was cross-sectional with respect to the time of data collection. The research was conducted in two consecutive qualitative and quantitative phases. The qualitative phase was designed based on the grounded theory approach and aimed to identify, conceptualize, and organize the major dimensions and components of an educational system model for the literacies required for life in the digital age. The quantitative phase employed a descriptive-survey design and was conducted to empirically examine and validate the model developed through the qualitative phase. The statistical population in the qualitative phase consisted of academic experts, university faculty members, and specialists with relevant knowledge and professional experience in the fields of digital literacy, educational management, educational systems, and related areas at Islamic Azad Universities in Mazandaran Province. A total of 20 individuals constituted the accessible expert population. Participants in this phase were selected through non-probability purposive sampling according to their expertise, academic background, familiarity with digital literacy and educational management, and ability to provide information relevant to the objectives of the study. Interviews and qualitative data collection continued until theoretical saturation was achieved, meaning that additional interviews no longer generated substantively new concepts, categories, or dimensions. Based on this criterion, theoretical saturation was reached after interviews with 13 experts, who constituted the final qualitative sample.

In the quantitative phase, the statistical population consisted of approximately 39,000 students enrolled at Islamic Azad Universities throughout Mazandaran Province. The required sample size was estimated using Cochran's formula, resulting in a sample of 381 students. Participants were selected using multistage cluster random sampling to provide adequate geographical representation of Islamic Azad University students across the province. For this purpose, Mazandaran Province was divided into three geographical regions comprising the eastern, central, and western areas, and two university branches were selected from each region. Accordingly, the selected branches were Neka, Sari, Qaemshahr, Babol, Chalus, and Tonekabon. The student populations of these branches were approximately 1,500, 9,500, 7,000, 9,000, 4,000, and 8,000 students, respectively. The quantitative sample was proportionally distributed according to the population size of each selected university branch. Consequently, 15 students were selected from Neka, 92 from Sari, 68 from Qaemshahr, 88 from Babol, 40 from Chalus, and 78 from Tonekabon, producing a total quantitative sample of 381 students. This sampling procedure was intended to increase the representativeness of the sample by incorporating students from university branches situated in different geographical areas of Mazandaran Province.

Data Collection Tools

Data were collected through two principal instruments corresponding to the qualitative and quantitative phases of the study. In the qualitative phase, semi-structured interviews were used to obtain detailed information from academic experts and specialists. The interview framework was developed in accordance with the primary research objective and focused on identifying the types of literacy required by university students for effective life and participation in the digital age, as well as the educational conditions, structures, resources, processes, and institutional mechanisms necessary for developing such literacies within Islamic Azad Universities. The semi-structured nature of the interviews enabled the researchers to maintain consistency around the principal research topics while also allowing participants to elaborate on their experiences, professional judgments, and interpretations. Probing and supplementary questions were employed when necessary to clarify responses and explore emerging concepts in greater depth. Data collection proceeded concurrently with qualitative analysis, and interviews continued until theoretical saturation was established after the thirteenth participant.

The findings derived from the qualitative phase provided the conceptual basis for developing the quantitative instrument. Accordingly, a researcher-made questionnaire comprising 53 items was constructed to operationalize and assess the dimensions identified in the proposed educational system model. The questionnaire covered 14 dimensions, including technological literacy, information literacy, media literacy, digital communication literacy, digital security and ethics literacy, critical thinking, problem-solving and technological innovation, lifelong learning and digital cultural awareness, educational policies and strategies, curriculum and educational content, teaching and learning methods, technological infrastructure and facilities, faculty competencies and attitudes, learner support, and the culture and values of digital learning. The questionnaire items were rated on a five-point Likert scale ranging from 1 to 5, with response alternatives corresponding to very low, low, moderate, high, and very high, respectively. Higher scores therefore represented a higher perceived level, importance, adequacy, or contribution of the respective indicators and dimensions within the proposed educational system for developing digital-age literacies.

The psychometric properties of the research instruments were evaluated through multiple procedures. Face validity and content validity were assessed through expert judgment. Specialists in relevant academic fields reviewed the interview framework and the researcher-made questionnaire in terms of clarity, relevance, comprehensiveness, appropriateness of wording, correspondence between the items and their intended constructs, and consistency with the objectives and conceptual framework of the study. Necessary revisions were subsequently made on the basis of expert feedback. In the quantitative phase, convergent validity was examined using the Average Variance Extracted (AVE) coefficient within the measurement model. The AVE values obtained for all dimensions exceeded the recommended threshold of 0.50, indicating that the indicators associated with each latent construct explained an adequate proportion of the variance in that construct and supporting the convergent validity of the measurement model. Reliability was evaluated using both Cronbach's alpha and composite reliability coefficients. The values obtained for all dimensions were greater than 0.70, demonstrating satisfactory internal consistency and construct reliability. Taken together, the results of the validity and reliability assessments indicated that the researcher-made questionnaire possessed adequate psychometric properties for evaluating the proposed educational system model among the target student population.

Data Analysis

Data analysis was performed separately and sequentially for the qualitative and quantitative phases in accordance with the exploratory mixed-methods design. In the qualitative phase, data obtained from the semi-structured interviews were analyzed using grounded theory procedures. The interview data were systematically reviewed, compared, conceptualized, and categorized to identify the major concepts and dimensions associated with an educational system capable of developing the literacies required for life in the digital age. The analysis involved the identification of initial concepts from participants' statements, the comparison and integration of conceptually related codes, and the organization of these concepts into broader categories and dimensions. Through constant comparison among interview data, emerging codes, and categories, the conceptual relationships among the components of the proposed model were progressively refined. The process continued alongside data collection until theoretical saturation was achieved and no substantively new categories or relationships emerged from additional interviews. The resulting qualitative framework was subsequently used as the foundation for developing the researcher-made questionnaire and for specifying the constructs examined during the quantitative validation phase.

In the quantitative phase, both descriptive and inferential statistical procedures were employed. Descriptive statistics, particularly the mean and standard deviation, were calculated to summarize the participants' responses and describe the distribution of scores across the dimensions and components of the proposed educational system model. Inferential analysis was performed using structural equation modeling based on the partial least squares approach in order to evaluate the measurement and structural components of the proposed model and examine the relationships among its latent constructs. The measurement model was assessed through relevant indicators of construct validity and reliability, including Average Variance Extracted, Cronbach's alpha, and composite reliability. Subsequently, the structural model was examined to determine the empirical adequacy of the relationships specified among the dimensions derived from the qualitative phase and to evaluate the extent to which the proposed educational system model was supported by the quantitative data. Statistical analyses and preliminary data management were performed using SPSS version 27, while partial least squares structural equation modeling was conducted using PLS software. The integration of the qualitative findings with the quantitative model-testing results provided the basis for developing and validating the final educational system model for the literacies required for life in the digital age among students of Islamic Azad Universities in Mazandaran Province.

Findings and Results

The qualitative phase involved 13 experts selected purposively from relevant academic and professional fields. Of these participants, five were women, representing 38.46% of the qualitative sample, and eight were men, representing 61.54%. Regarding professional experience, one participant had between 10 and 15 years of experience, accounting for 7.69% of the sample, while four participants had 16–20 years of experience, four had 21–25 years of experience, and four had 26–30 years of experience, each group representing 30.77% of the qualitative sample. Thus, most participants had more than 15 years of professional experience, indicating that the qualitative data were derived predominantly from individuals with substantial academic, managerial, technological, or educational experience.

The experts also represented diverse disciplinary backgrounds. Three participants specialized in information and communication technology, three in educational management, two in e-learning, and one participant each in educational technology, instructional design, educational policymaking, human-resource empowerment, and human-resource development. Information and communication technology and educational management therefore each accounted for 23.08% of the qualitative sample, e-learning accounted for 15.38%, and each of the remaining areas accounted for 7.69%. This disciplinary diversity provided complementary technological, pedagogical, managerial, and policy-oriented perspectives on the educational requirements of digital-age literacy.

The qualitative analysis was conducted using an exploratory grounded-theory orientation combined with inductive content analysis and categorization. Semi-structured interviews were transcribed and analyzed line by line, paragraph by paragraph, and sentence by sentence. Meaning units were identified, coded, compared continuously, and progressively grouped into conceptually related categories. MAXQDA 22 was used to manage the interview material, compare codes, organize categories, and examine conceptual relationships. Credibility was strengthened through repeated examination of the transcripts, participant checking, peer review, comparison of emerging codes with original statements, and systematic documentation of analytical decisions.

For the first qualitative research question concerning the literacies required for life in the digital age, 402 initial concepts were identified. Through continuous comparison, removal of conceptual duplication, and integration of overlapping codes, these concepts were reduced to 69 focused concepts. The emergence of new concepts diminished progressively across the interviews. No substantively new concept was identified in interviews 11 through 13, supporting theoretical saturation. Frequently recurring concepts included technology, learning, information, security, skills, communication, content, digital ethics, critical thinking, credible sources, time, privacy, creativity, artificial intelligence, research, professional development, lifelong learning, innovation, collaboration, and digital responsibility.

Examples of the initial coding process illustrated how participants' statements were transformed into focused concepts. Statements emphasizing the need for students and faculty members to use educational technologies produced codes relating to hardware and software familiarity, operating-system competence, installation and updating of educational applications, technical maintenance, and optimization of digital devices. Statements about differentiating scientific from unreliable information generated codes concerning source credibility, evaluation of authors and journals, comparison and integration of information, and critical evaluation of digital material. References to students becoming producers rather than merely consumers of content generated concepts such as educational content production, graphic and video editing, creativity, and digital knowledge sharing. Statements concerning appropriate online behavior produced codes related to professional etiquette, privacy, professional identity, and culturally appropriate communication. Similarly, discussion of cybersecurity generated codes concerning strong passwords, two-factor authentication, phishing recognition, and data security, whereas statements about continuous technological change generated concepts related to self-directed learning, emerging technologies, professional development, and lifelong digital learning.

The second qualitative research question addressed the components and indicators of an educational system capable of supporting development of these literacies. More than 300 initial concepts were identified from the interviews and were subsequently condensed into 59 focused concepts. The emergence of new categories decreased substantially after the tenth interview, and no substantively new concepts were found in interviews 12 and 13. Frequently recurring terms included policymaking, planning, strategy, digital education, technology, infrastructure, Internet access, learning management systems, faculty members, learning, content, curriculum, skills, technical support, educational workshops, digital content design, creativity, innovation, entrepreneurship, ethics, culture, values, responsibility, security, privacy, support, budgeting, critical thinking, interaction, participation, motivation, and technology-oriented cultural development.

The complete qualitative synthesis is presented in Table 1. It integrates the seven literacy dimensions with the seven educational-system dimensions identified through the analysis.

Table 1. Complete Qualitative Results for the Digital-Age Literacies and Educational-System Components

Domain	Main category	Focused concepts and indicators identified from the qualitative data
Digital-age literacies	Technological literacy and digital-tool management	Familiarity with computer and smartphone hardware; operating-system use; installation and updating of educational software; use of peripheral devices; file and folder organization; data backup; use of cloud storage and sharing services; management of multiple digital devices; technical maintenance and optimization; secure Wi-Fi use; device charging and maintenance; projector connection; digital printing; independent, safe, and purposeful use of technological tools
Digital-age literacies	Information and research literacy	Knowledge of reliable scientific databases; advanced scientific searching; selection of appropriate keywords; identification of different scientific-source types; evaluation of authors and journals; differentiation of current from outdated information; comparison and integration of multiple sources; scientific-content analysis; summarization and organization of research information; application of reliable information in academic projects; accurate referencing; recognition of false or manipulated information
Digital-age literacies	Media literacy and content production	Familiarity with digital media such as videos, podcasts, and infographics; production of educational textual and visual material; use of graphical and online editing applications; educational video editing; visual-design principles; effective dissemination of content; ethical and academic standards in content production; intellectual-property and copyright awareness; identification of misleading or fabricated content; use of digital media for learning and knowledge transfer
Digital-age literacies	Digital communication literacy	Professional etiquette in email and formal online communication; effective participation in webinars and virtual meetings; use of online collaborative tools; respectful communication on messaging applications and social networks; time management in online responses; development and management of professional digital identity; appropriate language in intercultural interaction; respect for others' privacy; online presentation and public-speaking skills
Digital-age literacies	Digital security and ethics literacy	Strong and unique passwords; two-factor authentication; identification of malware and viruses; recognition of phishing messages; management of application permissions and security settings; awareness of risks associated with sharing personal information; privacy protection in social networks; ethical production and redistribution of content; avoidance of impersonation, insult, and other unethical online behaviors; knowledge of cybercrime regulations and digital citizenship rights
Digital-age literacies	Critical thinking, problem-solving, and technological innovation	Verification of information and sources; logical and analytical examination of contradictory data; use of analytical software for academic problem-solving; identification of technical problems and development of technological solutions; application of technology to improve academic productivity; development of creative solutions to digital challenges; assessment of technological risks and consequences; creative collaboration in technology projects; awareness of emerging innovations such as artificial intelligence and augmented reality

Digital-age literacies	Lifelong learning and digital cultural awareness	Use of online courses for learning new skills; personal planning for digital-skill development; continued attention to emerging educational technologies; participation in online learning communities; understanding cultural differences in global digital communication; respect for diverse beliefs, languages, and cultures; positive orientation toward lifelong digital learning; use of technology for future professional development; sharing digital knowledge and experience
Educational system	Digital educational policies and strategies	Development of strategic digital-literacy plans; allocation of dedicated budgets for digital education; establishment of a technology-oriented university vision; managerial support for emerging educational technologies; incentive policies for technological initiatives; participation in national digital-transformation projects; revision of university missions according to technological change; strategic alignment of education with the digital environment
Educational system	Digital-oriented curriculum and educational content	Integration of digital skills into course syllabi; production and use of multimedia educational content; periodic curriculum revision; alignment of curricula with digital labor-market requirements; integration of media and information literacy; inclusion of cybersecurity, digital ethics, and critical thinking; use of digital resources in teaching; incorporation of student feedback; movement from static theoretical content toward practical digital competence
Educational system	Innovative digital teaching and learning methods	Use of learning management systems; videoconferencing and interactive platforms; blended face-to-face and online instruction; formation of online learning groups; technology-based student projects; digital educational games; student-generated content; digital problem-solving activities; active and interactive learning; change in faculty role from information transmitter to learning facilitator
Educational system	University technological infrastructure and facilities	Stable high-speed Internet; secure internal networks; smart-classroom equipment; access to educational software; digital libraries; electronic educational-content repositories; technical-support teams; continuous updating of educational systems; adequate hardware and software; systematic maintenance and technical support
Educational system	Faculty competencies and attitudes	Proficiency in educational software; competence in digital-content design; use of online academic networks; acceptance of digital education; positive attitude toward technological change; participation in digital-skills workshops; support for instructional innovation; observance of copyright; responsible use of technology; modeling ethical digital behavior for students
Educational system	Educational and technical learner support	Technology-skills workshops; basic and advanced digital-literacy courses; educational consultation on digital tools; technical guidance for students; support for student technology projects; financial and equipment support; training in digital security and privacy; online consultation and troubleshooting; support for self-directed digital learning
Educational system	Culture, values, and norms of digital learning	Promotion of ethical technology use; respect for rights of others online; institutionalization of technology-related ethical norms; digital responsibility; technology-awareness campaigns; digital-innovation festivals; encouragement of technology-oriented content production; promotion of digital entrepreneurship; creativity and experimentation; development of a safe, responsible, and innovation-oriented digital culture

At the final stage of the first qualitative analysis, the seven literacy dimensions were integrated around the central category of “empowering literacies for effective life in the digital age.” This overarching category captured the shared function of the seven literacy domains: enabling students to participate in digital environments consciously, ethically, creatively, safely, and effectively. Technological literacy emerged as a foundational competence because participants considered operational familiarity with hardware, software, cloud platforms, and digital tools a prerequisite for meaningful participation in digital learning. One expert summarized this position by emphasizing that students should know how to use computers, smartphones, educational applications, and basic software-management functions rather than merely having access to them.

Information literacy was interpreted as the ability to move from abundant digital data toward credible and usable knowledge. Participants repeatedly stressed source evaluation, effective scientific searching, comparison of information, appropriate use of academic databases, and responsible referencing. In this sense, access to information was considered insufficient unless students could assess its credibility, synthesize it, and use it according to academic and ethical standards.

Media literacy was conceptualized as both critical consumption and active production. Participants reported that students often used digital media extensively but were less consistently able to evaluate media messages, identify misinformation, observe copyright, or produce high-quality multimedia educational materials. Media literacy therefore included understanding media messages, recognizing their purposes and biases, and producing ethical, academically credible, and technically appropriate digital content.

Digital communication literacy represented the ability to build, maintain, and regulate purposeful relationships in digital environments. Participants emphasized professional email communication, respectful interaction, virtual-meeting competence, online teamwork, digital identity management, intercultural communication, privacy, and professional online presentation. Digital communication was consequently interpreted as a social and ethical competence rather than a simple capacity to transmit messages electronically.

Digital security and ethics literacy combined technical protection with responsible conduct. Experts emphasized strong authentication procedures, recognition of phishing and malware, privacy settings, careful sharing of personal information, copyright, respectful online behavior, and responsibility for the consequences of digital actions. The qualitative findings indicated that security and ethics reinforce one another by building trust and reducing unsafe or irresponsible digital practices.

Critical thinking, problem-solving, and technological innovation reflected the transition from passive technology consumption to analytical and creative technological participation. Participants emphasized evaluating digital claims, comparing contradictory information, using technology to solve academic and practical problems, assessing risks, developing technological solutions, participating in innovative projects, and becoming familiar with emerging technologies such as artificial intelligence and augmented reality.

Lifelong learning and digital cultural awareness represented an adaptive and higher-order dimension of digital competence. Participants described digital competence as continuously evolving rather than fixed. Online courses, webinars, learning communities, self-directed learning, professional development, openness to technological change, and intercultural sensitivity were therefore identified as essential. The findings suggested that digitally competent graduates need both the motivation to continually update their skills and the cultural awareness required to interact respectfully in global digital environments.

The analysis of the educational-system requirements resulted in a second central category: “an integrated educational system supporting digital-literacy development.” Participants indicated that digital literacy could not be developed sustainably through isolated courses or sporadic technological initiatives. Instead, development required coordinated policies, curricula, teaching practices, infrastructure, faculty competence, learner support, and institutional culture.

Digital educational policies and strategies emerged as the macro-level component that determines institutional direction. Participants repeatedly criticized fragmented or occasional use of technology and emphasized the need for formal strategies, dedicated budgets, managerial support, technology-oriented missions, incentives for innovation, and institutional coordination. Digital transformation was therefore regarded as a governance issue rather than merely a technical initiative.

The curriculum and content component emphasized systematic incorporation of digital competence into formal education. Participants described many existing curricula as insufficiently aligned with contemporary technological developments and the requirements of the digital labor market. They advocated integrating media literacy, information literacy, cybersecurity, digital ethics, critical evaluation, multimedia production, and practical technology-based activities into course content.

Innovative teaching and learning methods were another major component. Participants emphasized that uploading conventional lecture content to an online environment did not constitute genuine digital education. Effective digital pedagogy was associated with learning management systems, videoconferencing, blended learning, collaborative activities, digital projects, simulations, games, problem-based learning, and a transition from faculty-centered transmission toward facilitation of active learning.

Technological infrastructure was identified as a necessary enabling condition. Stable high-speed Internet, secure networks, smart classrooms, educational software, digital libraries, content repositories, continuous system updating, and responsive technical support were considered prerequisites for effective implementation. Participants noted that inadequate infrastructure reduced both faculty and student motivation and could undermine otherwise well-designed educational initiatives.

Faculty competence and attitudes were described as central human determinants of successful implementation. Technical competence, digital-content design, acceptance of technological change, innovative teaching, responsible use of digital resources, and ethical modeling were all emphasized. Participants maintained that faculty members who confidently and responsibly use technology are more likely to promote student engagement and create a sustainable digital-learning culture.

Learner support encompassed technical, educational, financial, and cultural assistance. Participants highlighted the need for orientation in digital systems, troubleshooting services, skills workshops, consultation, access to licensed software and equipment, security education, and support for student innovation. The findings indicated that the university's role in the digital era extends beyond content provision toward facilitation of students' capacity to learn independently and effectively.

Finally, culture, values, and norms of digital learning referred to the institutionalization of responsible, creative, and ethical technology use. Participants emphasized respect for others, privacy, responsible online participation, academic integrity, innovation, entrepreneurship, and a positive orientation toward experimentation and continuous learning. The resulting model therefore positioned culture and ethics as integral rather than peripheral components of digital transformation.

The integrated central category arising from these seven educational-system dimensions was defined as “the design and implementation of an integrated and multidimensional educational system based on policies, infrastructure, curriculum, teaching methods, faculty empowerment, student support, and digital cultural development for enhancing the literacies required for life in the digital age.”

Qualitative trustworthiness was examined through several complementary procedures. Internal coherence was strengthened by repeatedly comparing codes and categories with the original transcripts and reviewing the developing framework with academic supervisors and research colleagues. External descriptive validity was examined by presenting the categories to university experts and specialists in educational technology and higher education. Construct-related consistency was considered by comparing the emerging categories with established international digital-competence frameworks. An independent researcher also reviewed the coding process, with agreement in classification exceeding 85%. Analytical decisions, field notes, coding documents, and revisions were retained as an audit trail.

The qualitative model subsequently served as the basis for development of the researcher-made quantitative questionnaire. An initial pool of items was derived directly from the final open codes. Twelve experts in educational management, educational technology, curriculum studies, educational psychology, and higher-education policymaking evaluated item necessity, clarity, relevance, and comprehensiveness. An item-impact threshold of 1.50, a minimum Content Validity Ratio of 0.56, and a Content Validity Index threshold of 0.79 were applied. Redundant items were integrated, ambiguous items were revised, and inadequate items were removed. The final instrument contained 53 items. Thirty-four items assessed the seven digital-age literacy dimensions, while 19 items assessed the seven educational-system dimensions.

The quantitative sample consisted of 381 students. Of these, 146 were men, representing 38.3% of participants, and 235 were women, representing 61.7%. Regarding age, 71 participants were between 25 and 34 years old, accounting for 18.6% of the sample; 191 were between 35 and 44 years old, accounting for 50.1%; and 119 were aged 45 years or older, accounting for 31.2%.

Regarding educational level, 25 participants were undergraduate students, representing 6.6% of the sample; 116 were master's students, representing 30.4%; and 240 were doctoral students, representing 63.0%. With respect to field of study, 289 participants studied educational management (75.9%), 11 studied business management (2.9%), five studied educational technology (1.3%), 30 studied curriculum planning (7.9%), 10 studied educational sciences (2.6%), five studied language-related fields (1.3%), 21 studied engineering and technical disciplines (5.5%), and 10 studied basic sciences (2.6%).

Daily use of digital technology was low for 20 participants (5.2%), moderate for 186 participants (48.8%), and high for 175 participants (45.9%). Regarding the primary purpose of technology use, 159 students reported academic use (41.7%), 89 reported social use (23.4%), 47 reported recreational use (12.3%), and 86 reported other uses (22.6%). Thus, the sample was characterized by extensive daily exposure to digital technologies, with academic use representing the largest single category.

Descriptive results for the 14 dimensions are provided in Table 2.

Table 2. Descriptive Statistics for the Dimensions of the Proposed Model

Dimension	Minimum	Maximum	Mean	SD
Technological literacy and digital-tool management	2.40	5.00	4.01	0.59
Information and research literacy	2.83	5.00	3.95	0.52
Media literacy and content production	2.40	5.00	4.06	0.57
Digital communication literacy	3.00	5.00	4.16	0.47
Digital security and ethics literacy	2.20	5.00	4.10	0.64
Critical thinking, problem-solving, and technological innovation	2.50	5.00	4.14	0.59
Lifelong learning and digital cultural awareness	1.80	5.00	4.21	0.60
Digital educational policies and strategies	1.00	5.00	3.68	0.94
Digital-oriented curriculum and educational content	1.00	5.00	3.54	0.98
Innovative digital teaching and learning methods	1.00	5.00	3.78	0.76
University technological infrastructure and facilities	1.00	5.00	3.32	1.04
Faculty competencies and attitudes	1.67	5.00	4.00	0.73
Educational and technical learner support	1.33	5.00	3.56	0.96
Culture, values, and norms of digital learning	1.00	5.00	3.68	0.96

The descriptive findings indicate that the individual digital-literacy dimensions were generally rated highly. Lifelong learning and digital cultural awareness received the highest mean score, $M = 4.21$, $SD = 0.60$, followed by digital communication literacy, $M = 4.16$, $SD = 0.47$, and critical thinking, problem-solving, and technological innovation, $M = 4.14$, $SD = 0.59$. Digital security and ethics literacy also received a high mean, $M = 4.10$, $SD = 0.64$, followed by media literacy and content production, $M = 4.06$, $SD = 0.57$, technological literacy, $M = 4.01$, $SD = 0.59$, and information and research literacy, $M = 3.95$, $SD = 0.52$.

In contrast, evaluations of institutional and organizational conditions were more moderate. Faculty competencies and attitudes received a comparatively high mean of 4.00, $SD = 0.73$, whereas innovative teaching and learning methods had a mean of 3.78, $SD = 0.76$. Digital educational policies and strategies and digital-learning culture both had means of 3.68, while learner support had a mean of 3.56 and digital-oriented curriculum and content had a mean of 3.54. Technological infrastructure received the lowest mean, $M = 3.32$, $SD = 1.04$, and also exhibited the greatest dispersion. Taken together, these findings indicate that students perceived their personal digital capacities more positively than the institutional structures available to support digital learning. The comparatively large standard deviations for infrastructure, curriculum, learner support, policies, and digital culture also suggest unequal experiences of institutional digital provision.

The distributional assumptions were examined using the Kolmogorov–Smirnov test. Test statistics were .084 for technological literacy, .136 for information literacy, .135 for media literacy, .253 for digital communication literacy, .094 for digital security and ethics, .205 for critical thinking/problem-solving/innovation, .173 for lifelong learning and cultural awareness, .150 for policies and strategies, .123 for curriculum and content, .184 for teaching and learning methods, .129 for technological infrastructure, .191 for faculty competencies, .165 for learner support, and .173 for digital-learning culture. All tests were statistically significant at $p < .001$. Accordingly, the null hypothesis of normality was rejected for all dimensions. This distributional pattern further supported use of variance-based partial least squares structural equation modeling, which does not require multivariate normality.

The measurement model was evaluated through internal consistency reliability, composite reliability, convergent validity, indicator loadings, and discriminant validity. The complete measurement-model results are summarized in Table 3.

Table 3. Measurement-Model Reliability, Convergent Validity, and Indicator Loadings

Type	Construct / indicator	Cronbach's α	Composite reliability	AVE	Loading
Construct	Curriculum and educational content	.848	.908	.766	—
Construct	Faculty competencies and attitudes	.753	.858	.669	—
Construct	Learner support	.787	.904	.825	—
Construct	Teaching and learning methods	.724	.844	.644	—
Construct	Technological infrastructure and facilities	.897	.936	.829	—
Construct	Digital communication literacy	.701	.780	.503	—
Construct	Information literacy	.756	.831	.501	—
Construct	Digital security and ethics literacy	.837	.885	.607	—
Construct	Media literacy	.753	.835	.505	—
Construct	Technological literacy	.701	.808	.502	—
Construct	Digital-age literacies	.937	.943	.504	—
Construct	Educational policies and strategies	.845	.907	.764	—
Construct	Effective educational system for developing digital-age literacies	.945	.951	.510	—
Construct	Digital-learning culture and values	.893	.949	.903	—
Construct	Lifelong learning and digital cultural awareness	.835	.885	.610	—
Indicator 1	Use digital tools such as laptops and smartphones for academic activities	—	—	—	.764
Indicator 2	Install and update academic software	—	—	—	.662
Indicator 3	Organize digital files and data systematically	—	—	—	.705
Indicator 4	Use cloud services for storing and sharing data	—	—	—	.684
Indicator 5	Use cloud services safely and correctly	—	—	—	.600
Indicator 6	Identify reliable scientific databases such as Scopus and Google Scholar	—	—	—	.707
Indicator 7	Select appropriate keywords for information searching	—	—	—	.732
Indicator 8	Distinguish credible from noncredible sources	—	—	—	.600
Indicator 9	Analyze and summarize collected information	—	—	—	.725
Indicator 10	Apply collected information in projects and research	—	—	—	.655
Indicator 11	Validate information published on social networks and online sources	—	—	—	.610
Indicator 12	Produce textual or visual digital content for educational purposes	—	—	—	.663
Indicator 13	Use image and video editing tools for educational content production	—	—	—	.732
Indicator 14	Observe writing and ethical principles when publishing scientific content	—	—	—	.654
Indicator 15	Observe intellectual-property and copyright principles	—	—	—	.770
Indicator 16	Identify false or misleading digital content	—	—	—	.727
Indicator 17	Observe professional etiquette in online correspondence and virtual meetings	—	—	—	.600
Indicator 18	Use online collaboration tools in group projects	—	—	—	.654
Indicator 19	Manage online content to maintain a professional and trustworthy presence	—	—	—	.805
Indicator 20	Manage and protect personal digital reputation	—	—	—	.781
Indicator 21	Use strong passwords and two-factor authentication	—	—	—	.788
Indicator 22	Recognize and prevent cybersecurity threats	—	—	—	.825
Indicator 23	Configure privacy settings correctly	—	—	—	.694
Indicator 24	Share personal information only after ensuring digital security	—	—	—	.832

Indicator 25	Observe digital-ethics principles when producing or sharing content	—	—	—	.749
Indicator 26	Examine the source and accuracy of new information	—	—	—	.600
Indicator 27	Use digital technologies and analytical software to solve academic problems	—	—	—	.723
Indicator 28	Propose practical ideas for improving digital project processes	—	—	—	.600
Indicator 29	Consider ethical consequences of technological decisions	—	—	—	.638
Indicator 30	Use online resources such as MOOCs to learn digital skills	—	—	—	.629
Indicator 31	Respect cultural diversity in digital environments	—	—	—	.739
Indicator 32	Regard digital learning as part of professional development	—	—	—	.876
Indicator 33	Show interest in learning new digital skills	—	—	—	.846
Indicator 34	Use digital resources to develop future professional skills	—	—	—	.789
Indicator 35	University has explicit programs for digital-literacy development	—	—	—	.820
Indicator 36	University managers support innovative educational technologies	—	—	—	.900
Indicator 37	University strategies are aligned with digital-age needs	—	—	—	.900
Indicator 38	Course content incorporates practical digital skills	—	—	—	.868
Indicator 39	Course syllabi are updated in response to digital developments	—	—	—	.900
Indicator 40	Media- and information-literacy courses are incorporated into university programs	—	—	—	.858
Indicator 41	Faculty members use digital tools and LMS platforms in teaching	—	—	—	.759
Indicator 42	Online interactive activities strengthen learning	—	—	—	.788
Indicator 43	Teaching methods encourage digital creativity	—	—	—	.856
Indicator 44	University provides adequate Internet and network access	—	—	—	.903
Indicator 45	Students have adequate access to digital educational software	—	—	—	.922
Indicator 46	Technical support is available for university educational systems	—	—	—	.906
Indicator 47	Faculty members have adequate educational-technology skills	—	—	—	.818
Indicator 48	Faculty members have positive attitudes toward digital learning	—	—	—	.900
Indicator 49	Faculty members model ethical technology use	—	—	—	.727
Indicator 50	University conducts workshops to improve digital literacy	—	—	—	.909
Indicator 51	Students receive support in learning new technologies	—	—	—	.907
Indicator 52	University promotes a culture of informed technology use	—	—	—	.951
Indicator 53	University environment encourages digital creativity and innovation	—	—	—	.950

All Cronbach's alpha coefficients were at or above .701, and all composite-reliability coefficients exceeded .780, indicating acceptable to excellent internal consistency. AVE values ranged from .501 to .903 and therefore met or exceeded the conventional .50 criterion for convergent validity. Particularly high AVE values were obtained for digital-learning culture and values (.903), learner support (.825), and technological infrastructure (.829).

The 53 standardized indicator loadings ranged from .600 to .951. The strongest loadings were observed for the university's promotion of informed technology use (.951), encouragement of digital creativity and innovation (.950), access to educational software (.922), digital-literacy workshops (.909), student support for learning new technologies (.907), technical support for university educational systems (.906), Internet and network access (.903), and several university policy, curriculum, and faculty-attitude items at or near .900. Indicators with loadings between .600 and .700 were retained because they represented conceptually important aspects of multidimensional constructs and the corresponding construct-level reliability and convergent-validity indices remained acceptable. No item had a loading below .600.

Discriminant validity was examined using the Fornell–Larcker criterion. The supplied discriminant-validity matrix contained 16 constructs: curriculum and educational content; critical thinking, problem-solving, and technological innovation; faculty competencies and attitudes; learner support; teaching and learning methods; technological infrastructure; digital communication literacy; information literacy; digital security and ethics literacy; media literacy; technological literacy; digital-age literacies; educational policies and strategies; the effective educational system; digital-learning culture and values; and lifelong learning and digital cultural awareness. The diagonal square-root-of-AVE values ranged approximately from .711 to .951. According to the criterion applied in the analysis, the diagonal value associated with each construct exceeded its relevant interconstruct correlations, supporting empirical distinction among the constructs and confirming discriminant validity of the measurement model.

The structural model was evaluated using bootstrapped path coefficients, sample means, standard errors, t statistics, and significance levels. The results are presented in Table 4.

Table 4. Structural Path Coefficients and Significance Tests

Structural path	β (O)	Bootstrap M	STDEV	t	p
Digital-age literacies → Critical thinking, problem-solving, and technological innovation	.808	.808	.024	33.528	<.001
Digital-age literacies → Digital communication literacy	.790	.793	.020	39.523	<.001
Digital-age literacies → Information literacy	.827	.829	.017	47.417	<.001
Digital-age literacies → Digital security and ethics literacy	.763	.764	.024	31.284	<.001
Digital-age literacies → Media literacy	.835	.836	.022	38.198	<.001
Digital-age literacies → Technological literacy	.734	.737	.024	30.419	<.001
Digital-age literacies → Lifelong learning and digital cultural awareness	.803	.803	.022	37.195	<.001
Effective educational system → Curriculum and educational content	.890	.891	.012	74.457	<.001
Effective educational system → Faculty competencies and attitudes	.749	.750	.035	21.510	<.001
Effective educational system → Learner support	.814	.813	.021	39.042	<.001
Effective educational system → Teaching and learning methods	.774	.775	.026	29.624	<.001
Effective educational system → Technological infrastructure and facilities	.754	.755	.021	36.291	<.001
Effective educational system → Digital-age literacies	.478	.480	.041	11.775	<.001
Effective educational system → Educational policies and strategies	.885	.886	.008	116.095	<.001
Effective educational system → Digital-learning culture and values	.854	.854	.016	53.339	<.001

All structural relationships were positive and statistically significant. The standardized path coefficients associated with the higher-order digital-age literacy construct ranged from .734 to .835. The strongest relationship was with media literacy, β = .835, followed by information literacy, β = .827, critical thinking/problem-solving/technological innovation, β = .808, lifelong learning and digital cultural awareness, β = .803, digital communication literacy, β = .790, digital security and ethics literacy, β = .763, and technological literacy, β = .734. These results empirically supported the seven-dimensional structure identified during the qualitative phase.

The effective educational-system construct also showed strong positive relationships with each of its institutional dimensions. The strongest coefficient was observed for curriculum and educational content, β = .890, followed by educational policies and strategies, β = .885, digital-learning culture and values, β = .854, learner support, β = .814, teaching and learning methods, β = .774, technological infrastructure, β = .754, and faculty competencies and attitudes, β = .749. In addition, the effective educational system had a direct positive association with the overall digital-age literacy construct, β = .478, t = 11.775, $p < .001$. This finding provided direct empirical support for the central proposition of the model that strengthening the university educational system contributes to the development of students' digital-age literacies.

Bootstrap sample means were extremely close to the original path coefficients throughout the model, indicating stable parameter estimation. Standard errors were small, ranging from .008 to .041, and all t statistics greatly exceeded the 1.96 critical value. The largest t statistic was obtained for the relationship between the effective educational system and educational policies and strategies, t = 116.095, followed by the relationship with curriculum and educational content, t = 74.457. Thus, all hypothesized measurement and structural relationships were statistically supported.

The explanatory and predictive performance of the structural model was evaluated using R^2, adjusted R^2, and Q^2. Overall model-fit indices were also examined. These results are consolidated in Table 5.

Table 5. Explanatory Power, Predictive Relevance, and Overall Fit of the Model

Indicator / endogenous construct	R^2	Adjusted R^2	Q^2	Saturated model	Estimated model	Interpretation
Curriculum and educational content	.793	.792	.570	—	—	Strong explanatory and predictive performance
Critical thinking, problem-solving, and technological innovation	.652	.651	.373	—	—	Substantial explanatory and positive predictive performance
Faculty competencies and attitudes	.561	.560	.346	—	—	Moderate-to-substantial explanatory and predictive performance
Learner support	.662	.661	.514	—	—	Substantial explanatory and strong predictive performance
Teaching and learning methods	.599	.598	.354	—	—	Moderate-to-substantial explanatory performance
Technological infrastructure and facilities	.569	.568	.442	—	—	Moderate-to-substantial explanatory and predictive performance
Digital communication literacy	.625	.624	.265	—	—	Substantial explanatory and positive predictive performance
Information literacy	.684	.683	.279	—	—	Substantial explanatory and positive predictive performance
Digital security and ethics literacy	.583	.584	.327	—	—	Moderate-to-substantial explanatory and predictive performance
Media literacy	.697	.696	.319	—	—	Substantial explanatory and predictive performance
Technological literacy	.539	.538	.223	—	—	Moderate explanatory and positive predictive performance
Digital-age literacies	.459	.458	.268	—	—	Acceptable explanatory and positive predictive performance
Educational policies and strategies	.784	.783	.565	—	—	Strong explanatory and predictive performance
Digital-learning culture and values	.729	.728	.627	—	—	Strong explanatory and highest predictive performance
Lifelong learning and digital cultural awareness	.645	.644	.353	—	—	Substantial explanatory and predictive performance
SRMR	—	—	—	.085	.088	Both values below .10; acceptable overall fit
d_ULS	—	—	—	2.45	2.78	Limited discrepancy between saturated and estimated models
d_G	—	—	—	1.15	1.20	Relatively small geodesic discrepancy
Chi-square	—	—	—	185.32	197.46	Reported as supplementary fit information
NFI	—	—	—	.91	.89	Saturated model above .90; estimated model close to the conventional .90 benchmark

The R^2 values indicated that the model explained a substantial proportion of variance in most endogenous constructs. The largest R^2 was obtained for curriculum and educational content, $R^2 = .793$, indicating that 79.3% of its variance was explained by the model. Educational policies and strategies also demonstrated strong explanatory power, $R^2 = .784$, followed by digital-learning culture and values, $R^2 = .729$, media literacy, $R^2 = .697$, information literacy, $R^2 = .684$, learner support, $R^2 = .662$, critical thinking/problem-solving/technological innovation, $R^2 = .652$, and lifelong learning and digital cultural awareness, $R^2 = .645$.

The remaining R^2 values were .625 for digital communication literacy, .599 for teaching and learning methods, .583 for digital security and ethics literacy, .569 for technological infrastructure, .561 for faculty competencies and attitudes, and .539 for technological literacy. The overall digital-age literacy construct had the lowest R^2, at .459, indicating that the effective educational-system construct accounted for 45.9% of its variance. Although lower than the values obtained for the first-order dimensions, this value still represented meaningful explanatory power in an educational and behavioral model. Adjusted R^2 values were almost identical to the corresponding R^2 estimates, suggesting that the model's explanatory performance was not produced by unnecessary complexity.

All Stone–Geisser Q^2 values were positive, demonstrating predictive relevance for every endogenous construct. The highest Q^2 was found for digital-learning culture and values, $Q^2 = .627$, followed by curriculum and educational content, $Q^2 = .570$, educational policies and strategies, $Q^2 = .565$, learner support, $Q^2 = .514$, and technological infrastructure, $Q^2 = .442$. Positive predictive values were also obtained for critical thinking/problem-solving/innovation (.373), teaching and learning methods (.354), lifelong learning and digital cultural awareness (.353), faculty competencies and attitudes (.346), digital security and ethics literacy (.327), media literacy (.319), information literacy (.279), the overall digital-age literacy construct (.268), digital communication literacy (.265), and technological literacy (.223). The absence of zero or negative Q^2 values indicated that the model possessed predictive relevance across all assessed endogenous constructs.

Overall model fit was also acceptable. SRMR was .085 for the saturated model and .088 for the estimated model, both below the .10 criterion. The d_ULS values were 2.45 and 2.78 for the saturated and estimated models, respectively, while d_G values were 1.15 and 1.20. These results indicated a relatively limited discrepancy between the empirical and model-implied structures. Chi-square values were 185.32 for the saturated model and 197.46 for the estimated model. Because the analytical approach was prediction-oriented PLS-SEM, these chi-square values were considered supplementary rather than primary fit criteria. NFI was .91 for the saturated model and .89 for the estimated model; therefore, the saturated model exceeded the conventional .90 benchmark, while the estimated model was very close to that threshold. Considered together with SRMR, the substantial R^2 values, the positive Q^2 values, and the significant structural coefficients, the findings supported the adequacy of the proposed structural model.

Integration of the qualitative and quantitative results supported a multidimensional and interactive educational-system model for developing the literacies required for life in the digital age among students of Islamic Azad Universities in Mazandaran Province. The final model consisted of two interdependent domains.

The first domain represented the intended student outcomes and comprised seven foundational digital-age literacies: technological literacy and digital-tool management; information and research literacy; media literacy and digital-content production; digital communication literacy; digital security and ethics literacy; critical thinking, problem-solving, and technological innovation; and lifelong learning and digital cultural awareness. The qualitative analysis identified these seven dimensions inductively, while the quantitative results supported their empirical representation through positive and statistically significant relationships with the higher-order digital-age literacy construct.

The second domain represented the institutional conditions and educational processes necessary to develop these literacies. It comprised digital-oriented curriculum and educational content, digital educational policies and strategies, faculty competencies and attitudes, innovative digital teaching and learning methods, technological infrastructure and facilities, educational and technical learner support, and digital-learning culture, values, and norms. The quantitative analysis demonstrated strong relationships between the effective educational-system construct and all seven institutional dimensions.

Within the curriculum component, the findings emphasized regular revision of course syllabi in accordance with student needs and digital labor-market requirements, incorporation of practical technology-based projects, use of multimedia resources, and integration of digital competencies into formal curricular structures. Within policy and strategy, the model emphasized university-wide digital-literacy standards, development of student and faculty digital competence, allocation of resources, and alignment between institutional strategy and the requirements of a digital society.

Faculty competence constituted the human implementation mechanism of the model. The findings supported development of faculty competence in educational technologies and digital instructional design, positive attitudes toward innovation, readiness for change, and continued professional development. Teaching and learning methods constituted the pedagogical mechanism and incorporated blended learning, flipped approaches, interactive learning, project-based activities, problem-solving, formative monitoring, and timely feedback.

Technological infrastructure represented the operational foundation of the model and included stable Internet access, learning management systems, digital communication platforms, educational applications, laboratories and facilities for digital-skills development, and platforms for digital-content production. Learner support represented the facilitative mechanism through which technical assistance, educational consultation, digital-skills workshops, equipment support, and guidance could reduce barriers to digital participation and strengthen students' self-efficacy.

The cultural component represented the normative foundation of the model. It emphasized digital ethics, professional behavior in online environments, positive orientations toward technology, lifelong learning, innovation, entrepreneurship, intellectual property, privacy, responsibility, and sustainable institutionalization of digital competence.

The empirical relationship between the effective educational-system construct and the overall digital-age literacy construct, $\beta = .478$, $p < .001$, demonstrated that these institutional conditions collectively contribute to students' development of the required literacies. At the same time, the strong coefficients linking the educational-system construct to curriculum, policies, culture, learner support, pedagogy, infrastructure, and faculty competence demonstrated that the model operates as a system rather than as a collection of independent interventions.

Accordingly, the final model was characterized by vertical and horizontal integration. Vertical integration connected institutional policies and strategies with curriculum, implementation, learning processes, and evaluation. Horizontal integration required coordination among managers, faculty members, students, technical-support units, curriculum planners, and other university stakeholders. The model was also multidimensional because it incorporated technological, cognitive, informational, communicative, ethical, cultural, pedagogical, and managerial dimensions.

The findings further indicated that the components function interactively. Improving only one component would be insufficient to produce sustainable digital-literacy development. For example, a digitally oriented curriculum would have limited impact in the absence of adequate technological infrastructure or digitally competent faculty members. Similarly, technological infrastructure without appropriate pedagogy, policies, learner support, or ethical culture would not independently produce the intended educational outcomes.

The final validated central proposition of the study can therefore be expressed as the design and establishment of an integrated, dynamic, technology-based, and value-oriented educational system for developing the literacies required by university students in the digital age. In this system, policies and strategies provide structural direction; curriculum, pedagogy, faculty competence, technological infrastructure, and learner support provide implementation mechanisms; and digital culture and ethics provide normative continuity. Together, these components create the conditions for developing students who are technologically capable, information-literate, media-aware, communicatively competent, secure and ethical in digital environments, critically reflective, innovative, culturally aware, and committed to lifelong learning.

Overall, the convergence of the qualitative and quantitative findings supported the proposed model as an empirically grounded framework for Islamic Azad Universities in Mazandaran Province. The qualitative phase established the content and institutional architecture of the model, while the quantitative phase demonstrated acceptable measurement quality, significant structural relationships, substantial explanatory power, positive predictive relevance, and acceptable overall model fit. Consequently, the final model provides a coherent empirical representation of how university-level educational structures can support the development of the literacies required for effective life, learning, employment, and participation in the digital age.

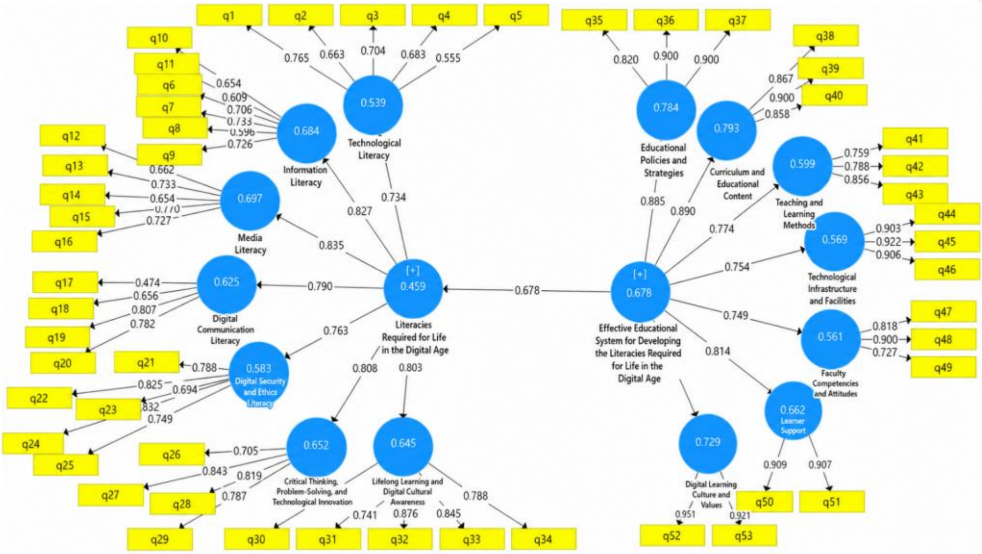

Figure 1. Final Model

Discussion and Conclusion

The present study aimed to develop and validate an integrated educational system model for the literacies required for life in the digital age among students of Islamic Azad Universities in Mazandaran Province. The findings produced a two-level model comprising, first, seven substantive dimensions of digital-age literacy and, second, seven educational-system dimensions required to support their development. The seven literacy dimensions included technological literacy and digital-tool management, information and research literacy, media literacy and content production, digital communication literacy, digital security and ethics literacy, critical thinking, problem-solving and technological innovation, and lifelong learning and digital cultural awareness. In parallel, the seven educational-system dimensions included digital educational policies and strategies, digital-oriented curriculum and educational content, innovative digital teaching and learning methods, technological infrastructure and facilities, faculty competencies and attitudes, educational and technical learner support, and digital-learning culture, values, and norms. The qualitative phase therefore indicated that digital literacy is not a singular technological skill but a multidimensional capability embedded in educational structures, while the quantitative phase confirmed the adequacy of this integrated conceptualization through acceptable reliability, validity, explanatory power, predictive relevance, and structural fit.

One of the main qualitative findings was that technological literacy represented a foundational component of students' ability to function effectively in digital learning environments. Participants emphasized the ability to operate digital devices, manage files and cloud services, install and update software, solve routine technical problems, and use digital tools independently and safely. This finding is consistent with studies that conceptualize digital competence as involving not merely access to technology but practical proficiency in selecting and using digital resources appropriately. Ghadardan et al. similarly identified technical and operational capabilities as fundamental dimensions of digital literacy, while Zhong et al. emphasized that contemporary digital literacy research increasingly treats technical competence as one component within a broader multidimensional structure (1, 2). The present findings extend this view by positioning technological literacy as a prerequisite that facilitates the functioning of other competencies such as information searching, media production, online communication, and digital problem-solving.

Information and research literacy also emerged as a major dimension. Participants highlighted the ability to search scientific databases, select appropriate keywords, assess source credibility, distinguish reliable from unreliable information, synthesize information from multiple sources, and apply correct referencing practices. This finding is particularly important because widespread access to digital information has increased both opportunities for academic learning and exposure to misinformation. The present result is aligned with Zhong et al., who emphasized that contemporary digital literacy increasingly incorporates critical information evaluation and information-management competencies (2). It is also consistent with Ghadardan et al., whose multidimensional understanding of digital literacy incorporated evaluative and cognitive competencies beyond technical access (1). Thus, the current findings suggest that universities should treat information literacy as a core academic capacity that directly affects research quality, scientific judgment, and students' ability to participate responsibly in knowledge-based environments.

The identification of media literacy and digital-content production as another central dimension also corresponds with previous evidence. The experts in the present study emphasized that students should be able not only to consume digital content but also to analyze, evaluate, produce, edit, and disseminate multimedia materials responsibly. This result is consistent with the conceptual model developed by Jasem Saheib Al-Sharifi et al., in which media literacy constituted a central foundation of virtual education and was directly linked with more effective participation in cyberspace-based learning environments (5). Similarly, Irannejad et al. demonstrated that educational interventions targeting citizenship competencies can improve media-related and digital citizenship behaviors, supporting the view that media literacy can be intentionally cultivated through structured educational programs (6). The present study therefore reinforces the argument that university students should be prepared to interpret media critically while simultaneously becoming competent and ethical producers of digital knowledge.

Digital communication literacy was another dimension confirmed by both qualitative and quantitative findings. Participants described effective online communication as involving professional etiquette, appropriate use of email and virtual platforms, collaborative interaction, professional identity management, responsiveness, respect for privacy, and intercultural sensitivity. This finding is compatible with the broader conceptualization of digital competence as encompassing communication, collaboration, and socially responsible interaction rather than only operational technological knowledge (15, 16). In higher education, these competencies are increasingly relevant because learning is frequently conducted through online discussions, collaborative projects, virtual meetings, and professional networks. The finding also suggests that communication competence should be treated as part of academic preparation because inappropriate digital communication can undermine collaboration, professional reputation, and participation in learning communities.

Digital security and ethics literacy also emerged as an essential component of the model. Participants highlighted the importance of strong passwords, authentication procedures, privacy protection, recognition of phishing and malware, ethical content sharing, copyright compliance, and responsible digital behavior. The importance of this dimension is supported by research emphasizing the role of perceived security in shaping users' experiences and sustained engagement with digital systems (7). From an educational perspective, security and ethics are closely connected because students need both the technical knowledge required to protect digital assets and the ethical judgment required to use digital environments responsibly. The present study therefore indicates that digital literacy education should not separate cybersecurity from digital citizenship, because safe participation depends on both protective behaviors and ethical self-regulation.

Another major finding was the identification of critical thinking, problem-solving, and technological innovation as a distinct dimension. This suggests that digital literacy should enable students to move beyond passive technology use toward analytical and creative application. Participants emphasized verifying information, interpreting contradictory evidence, using analytical software, generating technological solutions, evaluating risks, and engaging with emerging innovations such as artificial intelligence. This finding strongly aligns with Antara et al., who found that a problem-based flipped classroom model could improve both digital literacy and critical thinking, indicating that these competencies develop synergistically when students engage in active, technology-supported problem-solving (8). It is also consistent with Zhang and Pan, whose findings indicated that stronger digital literacy may reduce excessive chatbot dependency by promoting more reflective and independent interaction with artificial intelligence (9). Likewise, Kurdal and Kaplan showed that digital literacy is related to willingness to learn and use artificial intelligence, highlighting its importance for adaptation to emerging technologies (10). Together, these findings support the present model's inclusion of innovation and critical judgment as essential features of digital-age competence.

Lifelong learning and digital cultural awareness received the highest descriptive mean among the literacy dimensions. This suggests that students generally recognized the importance of continuous learning, technological adaptation, professional development, and culturally appropriate participation in digital spaces. This finding is consistent with Mahyiyuddin and Erlita's human-centered perspective on educational technology, which emphasizes that digital literacy must be connected with learner agency, motivation, academic interest, and sustainable learning rather than limited to mastery of particular tools (3). The high mean observed in the present study may indicate that students increasingly understand that digital competence is not static. As digital tools, artificial intelligence, and communication environments evolve, the capacity to continuously learn may become more important than mastery of any single technology.

An important contribution of the present study was the distinction between relatively strong individual digital competencies and comparatively weaker institutional conditions. Descriptive findings showed that most literacy dimensions had mean scores around or above 4.00, whereas several educational-system dimensions, including curriculum, infrastructure, learner support, policies, and digital culture, received lower scores. Technological infrastructure had the lowest mean and the largest dispersion. This pattern suggests that students may possess relatively strong personal readiness for digital engagement while perceiving the institutional environment as less consistently supportive. This result corresponds with Etemadi and Kasraei, who showed that organizational support is an important factor in e-learning performance and continued participation (11). It is also consistent with Bakrizadeh et al., who demonstrated that the relationship between digital literacy and e-learning is influenced by technology acceptance, suggesting that individual competence must be supported by usable and enabling technological environments (4).

The structural model further demonstrated that the effective educational system had a significant direct relationship with overall digital-age literacy, with a path coefficient of .478. This finding provides empirical support for the proposition that digital literacy is partly an institutional outcome rather than solely an individual characteristic. The educational system showed particularly strong relationships with curriculum and educational content, policies and strategies, digital-learning culture, learner support, teaching methods, infrastructure, and faculty competencies. These results indicate that improvement in students' digital competencies requires coordinated institutional intervention. This finding is compatible with technology-acceptance perspectives emphasizing that use of digital systems depends not only on technical availability but also on perceived usefulness, ease of use, and supportive organizational conditions (12). It also aligns with Etemadi and Kasraei's emphasis on organizational support in sustaining e-learning outcomes (11).

Among the educational-system dimensions, curriculum and educational content showed the strongest relationship with the higher-order educational-system construct. This finding suggests that digital transformation must be embedded directly in the formal learning experience rather than treated as an optional extracurricular addition. Participants emphasized updating syllabi, integrating media and information literacy, including digital-security and critical-thinking competencies, using multimedia resources, and aligning academic content with digital labor-market requirements. This result can be interpreted alongside Antara et al., who demonstrated that technology-supported instructional design can strengthen digital literacy and critical thinking when learning activities are organized around active problem-solving (8). Similarly, the findings of Jasem Saheib Al-Sharifi et al. support the integration of media literacy within virtual instructional models rather than treating it as an isolated competence (5). Consequently, curriculum appears to function as the principal institutional mechanism through which digital competencies can be systematically translated into learning outcomes.

Educational policies and strategies also demonstrated a very strong relationship with the higher-order educational-system construct. This finding emphasizes that digital transformation requires strategic governance, dedicated resources, coherent institutional priorities, and managerial support. Without these conditions, digital activities may remain fragmented across departments or depend excessively on individual faculty initiative. The importance of organizational conditions is consistent with previous findings showing that support structures influence the success and continuation of e-learning (11). Moreover, technology-acceptance theory suggests that institutional policies can indirectly affect technology use by shaping perceived usefulness, facilitating conditions, and expectations regarding digital tools (12). The present findings therefore indicate that digital-literacy development should be treated as a strategic university priority rather than as a temporary response to technological change.

Faculty competencies and attitudes represented another significant component of the model. The findings indicated that students' digital learning is supported when faculty members are competent in educational technologies, willing to use digital tools, able to design digital content, and capable of modeling responsible digital behavior. This result strongly aligns with the systematic review by Basilotta-Gómez-Pablos et al., which demonstrated that higher-education teachers' digital competence is multidimensional and includes technical, pedagogical, communicative, and professional competencies (15). Kakouei et al. similarly identified faculty digital competency as involving interconnected knowledge, skills, and attitudes rather than simple technological proficiency (16). Shojaat et al. further reported that digital literacy contributes to the development of teaching skills, supporting the view that teacher competence can directly influence instructional quality (13). Rajabi et al. also showed that teachers' digital literacy is related to their perceptions of educational-platform usability, suggesting that competence shapes readiness to engage with digital learning systems (14). These findings collectively support the present study's emphasis on faculty development as an indispensable component of institutional digital transformation.

The measurement and structural results further strengthened confidence in the proposed model. Cronbach's alpha and composite reliability values exceeded acceptable thresholds across constructs, AVE values supported convergent validity, indicator loadings were acceptable, and discriminant validity was supported. R^2 values demonstrated substantial explanatory power for many dimensions, especially curriculum, educational policies, digital-learning culture, media literacy, and information literacy. All Q^2 values were positive, indicating predictive relevance, while SRMR values were below .10, supporting acceptable overall model fit. These results suggest that the integrated model is not only conceptually coherent but also empirically defensible. Importantly, the convergence between qualitative findings and quantitative validation supports a central conclusion of the study: developing the literacies required for life in the digital age depends on the simultaneous interaction of student competencies and institutional educational conditions.

Overall, the findings of the present study support a systems-oriented interpretation of digital literacy. Digital competence is most effectively understood not as a discrete set of technical skills but as an interconnected structure involving technological capability, information judgment, media understanding, communication, security, ethics, critical thinking, innovation, and lifelong learning. At the same time, these competencies require institutional support through curriculum, policies, infrastructure, faculty competence, innovative pedagogy, learner support, and a digital-learning culture. This integrated interpretation is consistent with contemporary scholarship that increasingly views digital literacy as a multidimensional, contextual, and human-centered construct (2, 3). Accordingly, the final model provides a contextually grounded framework for aligning student competencies with the educational processes and institutional conditions required for meaningful digital transformation in higher education.

This study should be interpreted in light of several limitations. First, the quantitative phase was limited to students of Islamic Azad Universities in Mazandaran Province; therefore, the findings may not fully represent students in public universities, other provinces, or higher-education systems with different organizational and technological conditions. Second, the cross-sectional nature of the quantitative phase did not allow examination of changes in digital literacy or educational-system effectiveness over time. Third, the quantitative findings were based on self-reported responses, which may be affected by social desirability, response tendencies, or differences between perceived competence and objectively demonstrated performance. Fourth, although the qualitative phase reached theoretical saturation and included experts from several relevant disciplines, the number of interview participants was necessarily limited. Finally, rapid technological developments, particularly in artificial intelligence, may result in the emergence of new competencies that were not fully represented when the model was developed.

Future studies should validate the proposed model in other provinces, public universities, medical universities, technical institutions, and non-university higher-education environments in order to assess its generalizability. Longitudinal research is recommended to examine whether improvements in institutional components lead to measurable changes in students' digital competencies over time. Future researchers could also combine self-report instruments with performance-based assessments of information evaluation, cybersecurity, digital-content production, AI literacy, and problem-solving. Experimental or quasi-experimental studies may examine the effectiveness of educational programs designed according to the seven institutional dimensions identified in this model. Further research should also investigate the role of emerging competencies related to generative artificial intelligence, algorithmic literacy, data literacy, digital well-being, and human–AI collaboration, and examine whether these competencies should be incorporated as independent dimensions or as subcomponents of the existing model.

Universities should use the proposed model as an integrated framework for digital transformation rather than implementing isolated technological initiatives. Academic programs should systematically incorporate digital literacy into curricula, including information evaluation, media production, cybersecurity, digital ethics, critical thinking, digital communication, and continuous learning. Faculty-development programs should focus on digital instructional design, active and blended learning, ethical technology use, and emerging technologies. Universities should simultaneously strengthen Internet access, learning-management systems, digital libraries, technical support, licensed software, and facilities for digital-content production. Dedicated support services should assist students who experience technological or educational difficulties, while institutional policies should provide clear standards for privacy, cybersecurity, academic integrity, and responsible use of artificial intelligence. Finally, digital transformation initiatives should be periodically evaluated using measurable indicators so that universities can identify weaknesses, allocate resources strategically, and continuously improve the educational environment.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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