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Digital Maturity in Higher Education: A Model and Design Principles for Institutional Transformation

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This study aims to develop a digital maturity model (DMM) specifically for higher education and to identify design principles emerging from the model development process. Recognizing that existing maturity frameworks rarely reflect the unique mission, governance, and stakeholder complexity of universities, this study addresses a conceptual and practical gap by integrating evidence from the literature, expert validation, and institutional piloting. A Design and Development Research methodology was employed. The development process combined a systematic literature review, document analysis, semi-structured interviews with 12 domain experts, a 25-week iterative expert panel process to refine the dimensions, levels, and indicators, and pilot implementation across 18 universities. The resulting model comprises five dimensions (individual, education, managerial processes, research, and infrastructure), 19 sub-dimensions, and 104 indicators, organized across five qualitative maturity levels: awareness, partial implementation, strategic implementation, integrated implementation, and cultural transformation. Four design principles were derived from the development process, emphasizing holistic dimensional coverage, clear and unambiguous level definitions, appropriately concrete indicators, and practical applicability. The model provides institutions with a structured instrument for assessing digital readiness, prioritizing transformation initiatives, informing strategic resource allocation, and benchmarking progress over time. An accompanying guideline is intended to facilitate stakeholder engagement and evidence-informed decision-making. Theoretically, the study contributes an empirically grounded and iteratively validated maturity model specific to higher education, while also offering design principles relevant to maturity model development and digital transformation in academic contexts.

Introduction

Higher education institutions face growing pressure to adapt to rapid technological changes and evolving societal demands (Sporn & Godonoga, 2024). Advances in information and communication technologies are reshaping education, research, and management, creating

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new opportunities and challenges (Singun, 2025; Yavuz et al., 2023). Recent post-pandemic analyses show that digital transformation now advances beyond emergency remote teaching toward integrated digital pedagogy and student-centered innovation ecosystems (Mabotha & Ngcamu, 2025).

Common barriers, such as unclear vision and leadership, limited digital capabilities, fragmented practices, and cultural resistance, prevent universities from aligning technologies with academic goals and stakeholder needs, underscoring the need for structured frameworks to guide digital transformation (Lyngdorf et al., 2024; Singun, 2025). One prominent approach to addressing this need is the digital maturity model (DMM). Digital maturity models assess an organization's current digital capabilities, delineate key capability dimensions, and provide a structured roadmap for progressing from current to desired levels of digital maturity (Al-Ali & Marks, 2022; Kalender & Žilka, 2024; Rutkowski, 2021).

Although higher digital maturity supports effective technology use and institutional performance (Thordsen & Bick, 2023), most digital maturity models have been developed for organizations in general and therefore may not adequately reflect the distinctive missions and stakeholder complexity of universities (Bravo-Jaico et al., 2025). Consequently, institutions often rely on generic or ad hoc frameworks that overlook higher education–specific dimensions such as digital pedagogy, culture, and governance (Alfirević et al., 2025). Recent reviews indicate a shift toward broader models incorporating digital culture, inclusivity, sustainability, and stakeholder co-creation, though these dimensions remain underrepresented in practice (Kumar et al., 2024). Earlier work focused on isolated domains such as e-learning or IT infrastructure (Tocto-Cano et al., 2020). More recent frameworks, including those proposed by Al-Ali and Marks (2022) and MD4U, encompass areas such as strategy, culture, infrastructure, and student experience (Martínez et al., 2019). Collectively, the literature suggests that digitally mature universities integrate strategy, culture, and technology to enhance academic and administrative processes (Yavuz & Karaman, 2023).

A growing body of research emphasizes that higher education maturity frameworks should be validated in real institutional contexts and incorporate innovation alignment and impact pathways (Bravo-Jaico et al., 2025). Yet many models lack theoretical grounding and empirical links to improved performance (Teichert, 2019), and despite appealing notions of progression toward maturity, evidence of organizational benefits remains limited (Thordsen & Bick, 2023). Without rigorous validation and contextualization, models risk remaining high-level tools with little practical value, a gap repeatedly noted in recent reviews (Reyes Domínguez et al., 2025), particularly in the higher education sector.

While several influential frameworks such as European Commission's DigCompOrg (2015) and the Jisc (2019) digital capability model provide valuable conceptual maps, they are not primarily designed as operational instruments for institutional self-assessment and prioritized transformation planning. Existing frameworks typically remain at a normative or descriptive level, offering high-level categories but limited guidance on how universities can translate them into measurable, staged organizational action. DigCompOrg, for instance, was conceived as a self-reflection framework offering broad organizational elements rather than scored, level-based indicators (DigCompOrg, 2015), leaving institutions without a clear mechanism to translate their position into a concrete maturity stage or actionable next step. Similarly, the Jisc digital capability model provides a descriptive account of individual and institutional capabilities but does not specify measurable thresholds that would allow an institution to benchmark progress over time or compare itself systematically with peer institutions (Jisc,

2019). This absence of a staged, indicator-based architecture constitutes an important gap that the present study seeks to address.

The contribution of this study therefore lies not in redefining the broad domains of digital transformation, but in transforming them into an implementable governance tool. Through iterative expert validation, piloting, and refinement, the model translates abstract policy aspirations into observable indicators, decision pathways, and structured stages of progression that institutions can apply in practice. In this sense, the study seeks to complement existing conceptual frameworks with a more operational approach to institutional planning and decision-making.

Taken together, the literature reveals a persistent need for a research-based and operationally viable framework capable of guiding institutions from diagnosis to coordinated development. Addressing this need, this study develops a comprehensive DMM grounded in theory and practice and proposes design principles that support not only assessment but also institutional steering and prioritization. Drawing on the academic literature and design science methods, the study develops a structured framework for assessing and guiding digital transformation in institutional settings. The research questions guiding the study are presented below.

- What dimensions, maturity levels, and indicators should be included in a digital maturity model for higher education?
- What design principles can inform the development of a digital maturity model for higher education?

Conceptual Framework

This study is grounded in the maturity model development literature, which conceptualizes maturity models as comprising three core components: dimensions, levels, and indicators (Hummel & Schenk, 2019; Ifenthaler & Egloffstein, 2020; Maasouman & Demirli, 2016). Building on this conceptualization, the study addresses each research question through a distinct theoretical lens. The first research question, concerning the dimensions, levels, and indicators of a digital maturity model for higher education, draws on the descriptive, prescriptive, and comparative purposes of maturity models proposed by De Bruin et al. (2005). Accordingly, the present model is positioned as serving both descriptive and prescriptive functions. The second research question, concerning the design principles for developing a digital maturity model for higher education, is informed by the Design and Development Research (DDR) framework (Richey & Klein, 2007), particularly its emphasis on iterative development, validation, and pilot implementation. Together, these perspectives inform the model development process detailed in the Method section.

Method

This study employed Design and Development Research (DDR) as its methodological approach. DDR is a systematic approach to the design, development, and evaluation of products, tools, models, or processes (Richey & Klein, 2007).

Richey and Klein (2007) categorize DDR into two types. Type 1 DDR focuses on the design, development, and evaluation of a specific product, program, or tool within a particular context, where the resulting artifact itself is the primary outcome. Type 2 DDR, on the other hand, centers on examining a particular design, development, or evaluation process or model with the

aim of generating generalizable design principles, rather than producing a single context-bound product. Since this study aimed to develop and validate a model intended for application beyond a single institutional context, Type 2 DDR was adopted as the more appropriate methodological approach.

Participant Groups

The study involved interview participants, expert panel members, external expert reviewers, and pilot study participants. Descriptive information about these groups is presented in Figure 1.

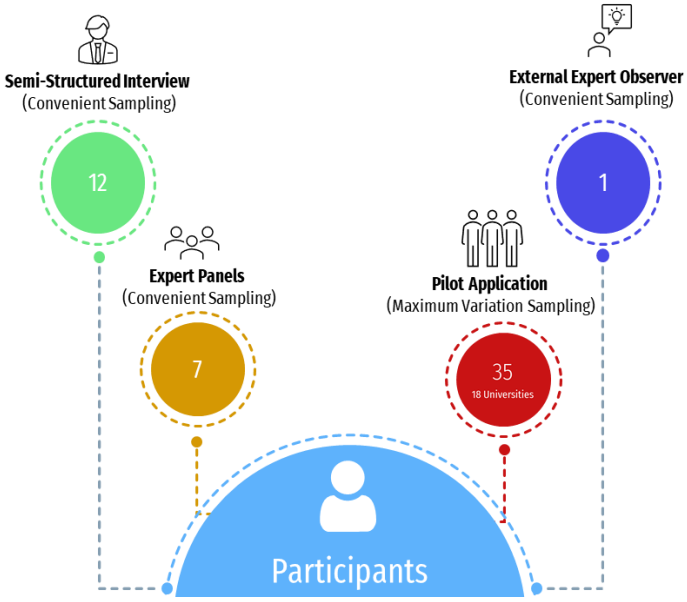


Figure 1. Overview of participant groups

Interview participants were selected using convenience sampling. The inclusion criterion was active involvement in digital transformation processes at higher education institutions. Accordingly, faculty members serving as digital transformation coordinators, staff of digital transformation offices, or academics with responsibilities related to institutional digital transformation were invited to participate. Twenty faculty members meeting these criteria were contacted via e-mail, and 12 volunteered to participate in the interviews. The expert panel consisted of seven professors who were members of the Higher Education Council's Distance Education Policies Commission and held senior administrative positions related to digital transformation or distance education, such as vice rector, director of a distance education center, or rector's advisor. The model was piloted with 35 participants from 18 universities selected through maximum variation sampling. Participants were introduced to the model and its implementation guideline, used the model to evaluate their own institutions, and subsequently participated in semi-structured interviews to provide feedback on its clarity, usability, and applicability. The final version of the model and the implementation guideline were additionally reviewed by an external specialist, an academic with expertise in digital transformation in the public sector.

Model Development Framework

The model development process was guided by the four-stage digital maturity model development framework proposed by Wißotzki and Koç (2013), which synthesizes prior research. The stages applied in this study are illustrated in Figure 2.

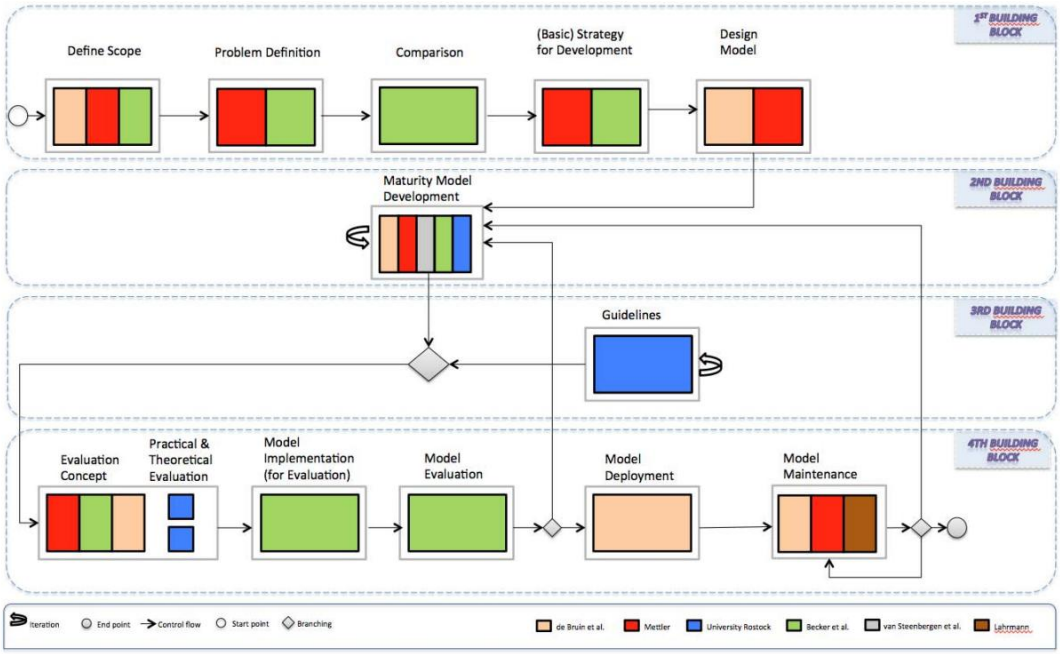


Figure 2. Model development framework adapted from Wißotzki and Koç (2013)

Following this framework, the model was developed through a multi-phase process. A literature review and semi-structured interviews with 12 experts first informed a preliminary indicator pool. Next, a 25-week expert panel iteratively refined dimensions, levels, and indicators. In the third phase, an implementation guideline was drafted, including a glossary, the rationale of the model, and implementation instructions. Finally, the model was piloted across 18 universities and revised based on feedback obtained during the pilot process and the external expert review.

Data Collection Tools

Three data collection tools were employed: a semi-structured interview form, a document review form, and an expert panel meeting report form. The three-item interview form was developed for faculty involved in digital transformation and reviewed by subject and language experts. The document review form was used to record key characteristics of relevant higher education studies. The expert panel meeting report form was used to document the discussions of a 25-week process involving seven specialists. Continuity throughout the process was supported through systematic documentation. Each session was led by a designated chair and documented by a rapporteur, who prepared written minutes summarizing the agenda, decisions, and outstanding issues. Although attendance varied across sessions due to panelists' availability, dimensions and indicators discussed in a panelist's absence were revisited in subsequent sessions before finalization. This process ensured that all panelists had an opportunity to contribute to the final model. All instruments were reviewed and refined based on expert feedback. The relationship between the model development framework and the research process is illustrated in Figure 3.

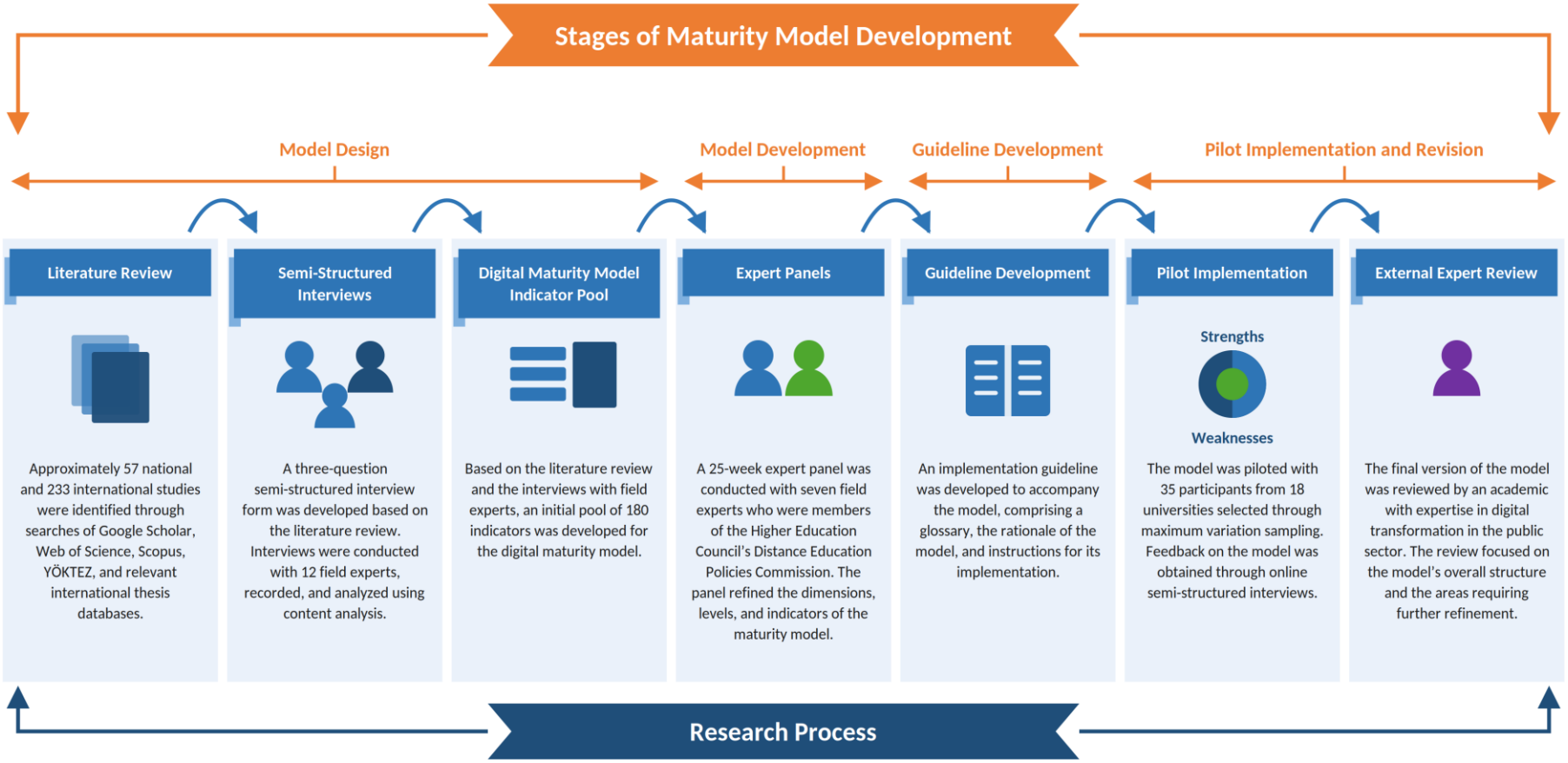


Figure 3. Research process

Data Analysis

Content analysis was used to analyze three sources of qualitative data: interviews with 12 field experts, meeting notes from the 25-week expert panel process, and 18 interviews conducted during the pilot implementation.

Content analysis is frequently preferred when data are obtained through interview and observation methods (Büyüköztürk et al., 2018), and is particularly useful for systematically organizing, classifying, and comparing textual data (Yıldırım & Şimşek, 2008). The analysis followed three main steps (McMillan & Schumacher, 2010): first, the recorded interviews were transcribed and the qualitative data were organized and coded; second, related codes were grouped into categories; and third, the categories were organized into broader themes. To enhance the trustworthiness of the analysis, two researchers coded the data independently and resolved coding discrepancies through discussion and consensus.

Validity and Reliability

To enhance the trustworthiness of the qualitative findings, the study addressed credibility, transferability, confirmability, and dependability through multiple data sources, prolonged engagement, expert and peer review, and systematic documentation (Merriam, 1998).

Specifically, dependability was supported through an audit trail. Interview transcripts, panel meeting records, and content-analysis coding records were digitally archived to provide transparency and traceability throughout the analytical process. A subject-matter expert subsequently reviewed these materials to assess the consistency and logical coherence of the coding and categorization. The audit trail, together with the external expert review, served as a mechanism for examining the consistency of the qualitative analysis. Although an inter-coder reliability coefficient was not calculated, two researchers independently coded the data and subsequently discussed discrepancies until consensus was reached. Collectively, these procedures enhanced the rigor, transparency, and trustworthiness of the qualitative analysis.

Findings

RQ1- DMM in Higher Education

RQ1-a) Dimensions of DMM in Higher Education

The dimensions were identified by integrating findings from the literature review, semi-structured interviews, and expert panels. First, the literature on digital maturity models in higher education and digital transformation frameworks was analyzed. This analysis identified the following dimensions: Education, Content and Curriculum, R&D and Collaboration, Community Service, Infrastructure/Technology, Communication, Culture, Individual, and Strategy. The dimensions of the analyzed studies are presented in Table 1.

Table 1. Dimensions obtained from the literature review

		Education	Content and Curriculum	R&D and Collaboration	Community Service	Infrastructure/Technology	Communication	Culture	Individual	Strategy	Leadership and Management	Qualifications/Professional Development	Organization/Institution	Campus
Digital Transformation in Higher Education	Kuzu (2020)	X		X	X						X			
JISC Digital Transformation Framework	Jisc (2019)	X	X	X		X	X							
DMM for Universities	Swanson (2020)							X		X		X	X	
KPMG Framework	Parker (2020)	X				X	X		X	X	X			
Maturity Model for Educational Institutions	Egloffstein and Ifenthaler (2021)	X				X		X	X	X	X		X	
Assessing Your School's DMM	Ae-MoYS (2011)		X			X		X			X	X		
Digital Maturity Framework for Higher Education Institutions	Đurek et al. (2018)	X		X	X	X		X			X			
DigCompOrg Framework	DigCompOrg (2015)	X	X	X		X					X			
Microsoft Education Transformation Framework for Higher Education	Microsoft (2018)	X		X					X					X
Digital Transformation in Higher Education	Gümüşoğlu (2017)				X				X				X	
	f	7	3	5	3	6	2	4	4	3	6	2	3	1

Table 1 shows that Education, Leadership and Management, Infrastructure/Technology, R&D and Collaboration, Culture, and Individual were among the most frequently represented dimensions in existing maturity models. Conversely, dimensions such as Campus, Qualifications/Professional Development, Communication, Content and Curriculum, Community Service, Strategy, and Organization/Institution were less frequently represented. These findings informed the subsequent expert-panel discussions.

The second data source used to determine the dimensions was the semi-structured interviews. Analysis of the semi-structured interviews identified six dimensions: Individual, Education, Technology, Management and Process, Research, and Community Service. These dimensions closely align with those identified in the existing DMM literature. A representative participant view is presented below:

> *"Digital transformation in higher education can be defined as updating education, research and administrative (administrative and business processes) processes in*

> *accordance with the possibilities of developing technology." [Expert Panel Phase: Expert Panelist 1]*

The expert panels served as a further data source for determining the dimensions. Drawing on the literature review and the interview findings, the expert panel refined the dimensions with the aim of developing a holistic framework aligned with the missions and organizational structures of higher education institutions. A representative panelist comment is provided below:

> *"... The dimensions of Education-Service to Society-Research seem to be the mission of universities and based on it. Process-Technology-Human is the triad that all institutions address in digital transformation. For this reason, there should be a grouping specific to the university." [EPP: EP2]*

Following the pilot implementation, participant feedback on the proposed dimensions was reviewed by the expert panel, and the model was revised accordingly. The final dimensions are presented in Figure 4.

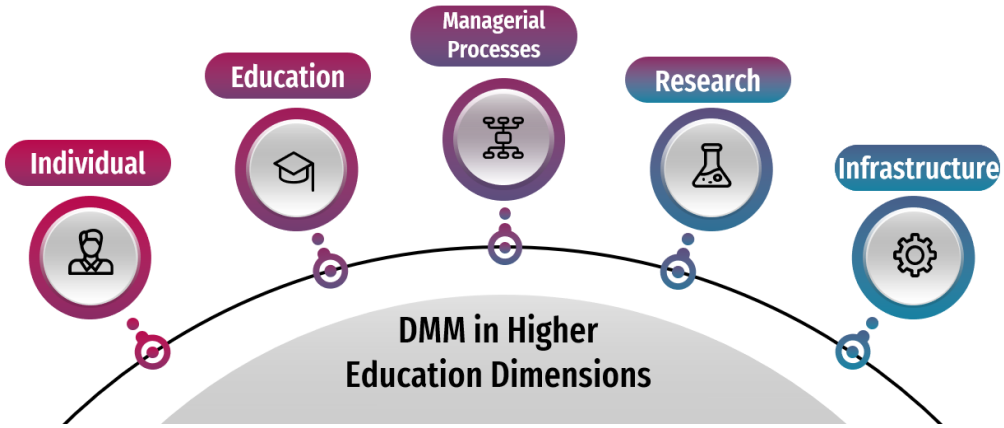


Figure 4. DMM in higher education dimensions

In the revised model, the six initial dimensions were consolidated into five by merging conceptually overlapping categories and integrating administrative components into managerial processes.

The final model comprises five dimensions: Individual, Education, Managerial Processes, Research, and Infrastructure. Individual reflects the central role of university stakeholders in digital transformation, while Education encompasses instructional activities. Managerial Processes addresses the digital transformation of institutional and administrative processes. Research represents the university's research mission and its engagement with university–industry–society collaboration. Infrastructure encompasses the technological and institutional infrastructure required to support digital transformation.

RQ1-b) Levels of DMM in Higher Education

The literature review was the first data source used to identify the maturity levels. Existing digital maturity models were systematically examined, and the levels identified are presented in Table 2.

Table 2. Maturity model levels identified in the literature

		None/Basic/Missing	Beginning/Awareness	Digitisation	Digitalization	Static	Reactive	Innovative/Good practices	Managed/Controlled	Digitalization Defined	Conceptual Definition	Optimised	Standardised/Advanced	Transformed/Mature/Artist	Proactive/Active/Competent/Expert	Safe	Integrated/Experienced	Strategic	Middle	1/2/3/4/5	f
Digital Maturity Assessment Framework	Wernicke et al. (2021)		X	X	X									X							4
Maturity Model of Learning Enterprises	Cobb & Steele (2016)					X	X	X							X						4
Levels of the Maturity Model	Knosp et al. (2018)		X						X	X		X									4
Achieving Digital Maturity	Kane et al. (2017)	X						X	X			X	X								5
Digital Accessibility Maturity Model	Byrne-Haber (2023)		X						X	X		X									4
Three-Stage Maturity Model	Ganzarain & Errasti (2016)		X						X	X				X							4
Digital Maturation Framework in Schools	Balaban et al. (2018)	X	X											X	X	X					5
Schools' Digital Maturity Frameworks	Redep et al. (2017)	X	X											X	X	X					5
DREAMY Model	De Carolis et al. (2017)		X						X	X				X			X				5
DMM	Azhari et al. (2014)		X							X	X			X			X				5
Industry 4.0 Maturity Model	Gökalp et al. (2017)	X	X						X	X	X	X									6
Digital Maturity Assessment Model	Jeffreys (2021)		X				X			X		X						X			5
My Digital Transformation Charts	Kane et al. (2015)		X											X					X		3
Digital Maturity Index	Reyes-Tagle et al. (2021)		X					X						X					X		4
IMPULS Model	Lichtblau et al. (2015)		X										X	X	X		X				5
Industry 4.0 Readiness and Maturity Model	Schumacher et al. (2016)																			X	1
Project Management Maturity Model	Eby (2022)																			X	1
	f	4	13	1	1	1	2	3	6	7	2	5	2	9	4	2	3	1	2	2	

Table 2 demonstrates considerable variation in how maturity levels are expressed. Most models employ qualitative categories, complemented in some cases by numerical scales (e.g., 1–5). Qualitative labels range from awareness or basic initiation at early stages, to defined, competent or strategic at intermediate levels, and to advanced, managed or transformed at higher stages. The reviewed models typically comprise between three and six levels.

Expert panels served as another key source for determining maturity levels and built upon insights from the literature review. Panelists refined the proposed level structure, considering whether the categories were clearly defined, sufficiently differentiated, aligned with the indicators, and representative of the digital transformation process. Selected panel perspectives are provided below:

> *"Should we begin with a term such as awareness for the first level? Expressions such as none, non-existent, or weak may be perceived as offensive. In addition, all universities moved toward digital transformation during the pandemic, albeit to different extents, and many institutions therefore carry out at least basic activities digitally. For this reason, I do not think that a term expressing absence would be appropriate." [EPP: EP6]*

During the pilot implementation, participants reported that dividing each maturity level into four percentage-based categories (25%, 50%, 75%, and 100%) made classification confusing and difficult. The expert panel therefore decided to remove these percentage subdivisions. Following these revisions, the final maturity levels are presented in Figure 5.

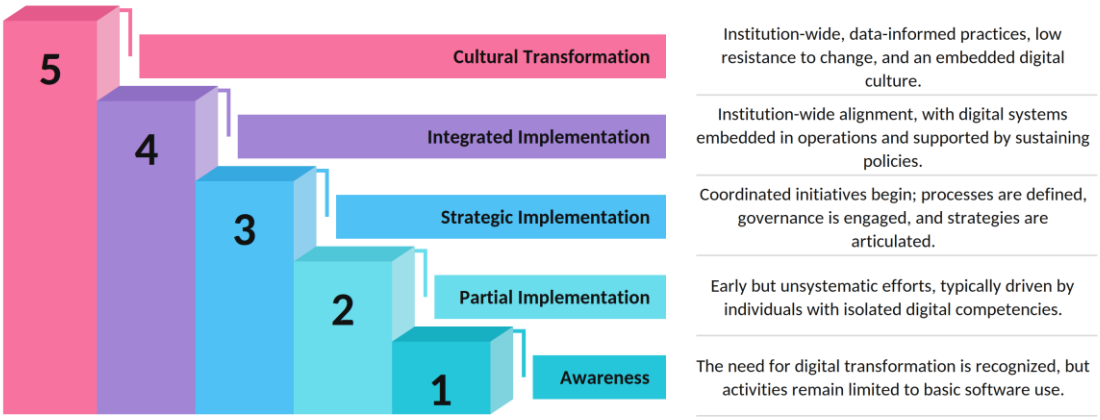


Figure 5. Levels of DMM in higher education

Awareness reflects recognition of the need for digital transformation, although activities remain limited to basic software use. Partial implementation signals early but unsystematic efforts, typically driven by individuals with isolated digital competencies. Strategic implementation marks the onset of coordinated initiatives, where processes are defined, governance is engaged, and strategies are articulated. Integrated implementation denotes institution-wide alignment, with digital systems embedded in operations and supported by sustaining policies. Finally, cultural transformation represents institution-wide, data-informed practices, low resistance to change, and an embedded digital culture, with the institution demonstrating advanced digital maturity.

RQ1-c) Indicators of DMM in Higher Education

Indicators, the final component of the model, were developed after determining the dimensions and levels. Initially, 74 indicators were identified from 13 sources in the literature. Semi-structured interviews generated 58 additional candidate indicators by exploring the scope of universities' digital transformation, and the expert panels proposed a further 48, resulting in an initial pool of 180 candidate indicators. These were grouped according to the model's dimensions. Panelists reviewed the grouping and relevance, and necessary revisions were made, resulting in the final set of indicators.

Following expert-panel review, the Individual dimension comprised 11 indicators across four sub-dimensions: students, instructors, administrators, and administrative staff.

Sub dimensions	Indicators
Student	a) Conducting activities (such as seminars, workshops, club activities, etc.) aimed at improving students' digital literacy skills, b) Providing access to digital learning resources, tools, and content explaining their usage (educational videos, guides, instructions, applications, etc.), c) Providing e-learning environments for students to acquire the ability to develop digital content (assignments, projects, theses, etc.).
Instructor	a) Providing activities (such as training, information sessions, seminars, etc.) and environments to enhance the digital literacy skills of teaching staff b) Providing environments for training teaching staff to use digital tools and environments effectively in their classes, c) Providing e-learning environments for teaching staff to gain the ability to develop digital course content.
Administrator	a) Providing environments for training and providing activities (such as education, events, seminars, etc.) to enhance the digital literacy skills of administrators, b) Measuring and monitoring the levels of IT usage among administrators, c) Conducting information, guidance, and incentive activities to support administrators in managing innovative practices within their areas of responsibility.
Administrative Staff	a) Providing environments for training and providing activities aimed at improving the digital literacy skills of administrative staff, b) Measuring and monitoring the levels of IT usage among administrative staff.

Figure 6. Sub-dimensions and indicators of the individual dimension

Figure 6 presents four sub-dimensions (students, instructors, administrators, and administrative staff) and 11 indicators addressing digital transformation practices for higher education stakeholders. The indicators address the development of digital competencies, engagement with emerging technologies, and the adoption of innovative practices. They also include the use of digital systems to support timely decision-making and regular training to strengthen stakeholders' digital competencies.

The indicators for the Managerial Processes dimension were then developed. Panelists suggested that these indicators should cover university administrative units and be supported with explanations and examples, noting that "units can be included as indicators since different units may have different digitalization processes." The resulting sub-dimensions and indicators are presented in Figure 7.

Sub dimensions	Indicators
1. Digitalization in Asset Management **2. Digitalization in Administrative Processes** **3. Online Services**	a) Legal Affairs Office
	b) Student Affairs
	c) Health, Culture, and Sports
	d) Construction and Technical Services
	e) Administrative and Financial Affairs
	f) Personnel Affairs
	g) Strategy Development
	h) Library and Documentation
	i) Press and Public Relations/Communication Coordinatorship
	j) IT
	k) Application and Research Centers
	l) Other Units Affiliated with the Rectorate (such as the Directorate of Projects Coordination, Office of External Relations, Education, and Instruction Coordination, etc.)

Figure 7. Sub-dimensions and indicators of the managerial processes dimension

Figure 7 presents three sub-dimensions (Digitalization in Asset Management, Digitalization in Administrative Processes, and Online Services) comprising 12 administrative units used as indicators. Unlike other dimensions, these units were defined directly as indicators and supported with brief explanations. Digitalization in Asset Management entails managing financial, physical, technical, and human resources through digital systems. Digitalization in Administrative Processes addresses the use of digital platforms to oversee and streamline institutional operations and support personnel and students. Online Services encompass the delivery of institutional services to stakeholders via digital applications.

To illustrate how the indicators translate into institutional practice across maturity levels, the Online Services sub-dimension can be considered as applied to Student Affairs. At the Awareness level, student-facing services such as appointment scheduling or document requests are handled manually. At the Partial Implementation level, unsystematic digital tools begin to emerge; for instance, a basic online appointment form for academic advising may be introduced but used inconsistently across departments. At the Strategic Implementation level, a defined digitalization strategy enables the systematic deployment of tools such as a thesis appointment system. At the Integrated Implementation level, these systems are interconnected with the university's broader digital infrastructure, for example through a graduate tracking system that automatically draws on student activity records across units. Finally, at the Cultural Transformation level, such digital services operate as a sustainable and expected standard of institutional practice. This progression illustrates how the same functional need manifests with increasing digital sophistication across the model's five maturity levels.

Following this, the Education dimension was prepared with 19 indicators across five sub-dimensions (content and material, methods and digital pedagogy, environment and tools, openness in education, and support) as presented in Figure 8.

Sub dimensions	Indicators
1. Content and Material	a) Sharing course materials such as syllabi, presentations, reading materials, videos, etc. in online environments,
	b) Empowering instructors to create content and materials using digital technologies.
2. Methods and Digital Pedagogy	a) Utilizing innovative teaching approaches suitable for digital environments,
	b) Integrating digital competencies and domain-specific innovations/updates into the curriculum,
	c) Employing assessment methods suitable for digital environments,
	d) Providing online feedback in digital learning environments.
3. Environment and Tools	a) Providing integration of Student Information System (SIS) and Learning Management System (LMS) for all courses,
	b) Utilizing simulators, virtual laboratories, etc., based on innovative approaches such as virtual reality and augmented reality,
	c) Offering live class environments for instructors as needed,
	d) Providing infrastructure for instructors to create and publish MOOC courses.
4. Openness in Education	a) Implementing practices for making course materials prepared by instructors available in open access,
	b) Encouraging students to participate in free courses on national and international MOOC platforms,
	c) Guiding and encouraging instructors to publish courses on national and international MOOC platforms,
	d) Conducting continuous education activities online outside of diploma programs.
5. Support	a) Organizing training and information events on the use of new technologies in educational environments,
	b) Providing software support for content development, assessment, and plagiarism detection that can be used in teaching and learning processes,
	c) Providing appropriate technological solutions for disabled groups,
	d) Providing mechanisms to meet the instant needs and demands of students and instructors regarding materials, hardware, content, and counseling,
	e) Providing online information and guidance services as part of administrative and academic support for students.

Figure 8. Sub-dimensions and indicators for the education dimension

Figure 8 outlines five sub-dimensions. Content and Material addresses the development and sharing of multimedia-based resources. Methods and Digital Pedagogy concerns innovative teaching and assessment practices in digital settings. Environment and Tools includes access to platforms, software, and training. Openness in Education relates to open access initiatives, including OERs and MOOCs. Finally, Support encompasses services that ensure the usability and sustainability of digital provision, such as orientation, guidance, and technical assistance.

For the Research dimension, expert panels identified 13 indicators grouped under three sub-dimensions: guidance and support, research process and monitoring, and sharing research results.

Sub dimensions	Indicators
1. Guidance and Support in Research	a) Providing online support/guidance/training services for faculty members during their research endeavours.
	b) Offering online mechanisms that provide general or personalised notifications about publications and innovative practices related to research areas for faculty members (such as SMS, mobile notification systems, digital subscriptions, etc.).
	c) Establish procedures to address researchers' hardware and software needs during the research process.
	d) Support for the use of new technologies during different stages of research processes, including data collection, analysis, and implementation.
2. Research Process and Monitoring	a) Management and monitoring of scientific projects (e.g., TÜBİTAK, BAP, KOSGEB) in digital environments.
	b) Providing virtual/online laboratory facilities for national and international R&D purposes to academic staff for research.
	c) Monitoring and ensuring visibility of university collaborations with stakeholders in research through digital platforms (e.g., Project Marketplace).
	d) Supporting the university library with digital publications and providing on/off campus access.
3. Sharing Research Results	a) Monitoring scientific activities within the university digitally based on parameters such as research type, topic, method, etc.
	b) Online publication of academic studies conducted within the university or related information through the university's institutional open access system, following ethical standards.
	c) Sharing of research findings with the public in a manner beneficial to society via digital platforms.
	d) Conducting, monitoring, and sharing outcomes of processes related to intellectual property, utility model, patent applications, etc., in an online environment.
	e) Facilitating online announcements, planning, monitoring, and sharing of collaborative research endeavors with stakeholders.

Figure 9. Sub-dimensions and indicators for the research dimension

Figure 9 identifies three sub-dimensions. Guidance and Support in Research includes assistance with digital research processes, project units, and inter-institutional collaboration. Research Process and Monitoring refers to conducting and tracking national and international projects on digital platforms. Sharing Research Results covers the dissemination of outputs through digital channels in line with intellectual property and ethical standards. For the Infrastructure dimension, expert panels identified 25 indicators across four sub-dimensions (effective communication and integration, innovation, sustainability and open access, and hardware and software accessibility) as shown in Figure 10.

Sub dimensions	Indicators
Effective communication and Integration	a) Establishment of support/communication points (e-mail, call centre, support ticket system, etc.) for faculty members and students within the institution,
	b) Ensuring compatibility and interactive communication among the technologies/software being used.
Innovation	a) Providing guidance/mentoring to units regarding the selection of new technologies,
	b) Monitoring and openness to innovative technologies (mobile technologies, Internet of Things, blockchain, smart systems, palm recognition, etc.) in university management processes,
	c) Tracking and openness to innovative technologies (interactive whiteboards, PCs, Internet of Things-supported classroom environments, card access systems, internet connectivity, etc.) in university teaching processes.
Sustainability and Open Access	a) Creation of a sustainable common architecture and documentation for the continuous improvement and integration of software within the university,
	b) Availability of technical control, maintenance and update mechanisms for the improvement and sustainability of software and hardware,
	c) Provision of qualified human resources (human resources experienced in information processing) in terms of sustainability and the existence of practices for their protection,
	d) Implementation of sustainable campus practices (recycling, clean and renewable energy, monitoring energy consumption, measuring carbon footprint, etc.),
	e) Availability of software and/or hardware solutions ensuring uninterrupted sustainability of digital services,
	f) Existence of an open archive system integrated with the National Academic Archives.
Hardware and Software Accessibility	a) Ensuring on-campus and off-campus access to software provided by the university to stakeholders,
	b) Provision of short-term technological resource loans to faculty members and students for educational purposes,
	c) Licensing of software used in courses for personal use by faculty members and students by the university,
	d) Provision of internet access support throughout the campus,
	e) Presence of systems facilitating campus life and learning processes for people with disabilities,
	f) Websites and social media accounts being user-friendly, usable, supporting multiple languages and disability conditions, mobile-friendly, and continuously updated to ensure institutional visibility,
	g) Providing the necessary environments for education and research related to priority areas (artificial intelligence, virtual reality laboratories, robotics laboratories, makerspaces, etc.),
	h) Presence of subscriptions to digital databases and digital resources, allowing access to them under a single umbrella,
	i) Providing the infrastructures of LMS and Live Course Systems for the execution of teaching activities at the university,
	j) Presence of digital campus applications at the university (campus card, license plate recognition system, heating, cooling, and electricity control with IoT systems),
	k) Provision of digital services at the university (e-canteen, medical appointment, e-club services, etc.),
	l) Using a common design language in the software and system interfaces used / Ensuring digital standardisation
	m) Development of a risk-based security strategy that effectively detects, responds to, and prevents security threats,
	n) Providing students with access to technologies such as internet, digital card refill kiosk, etc. in campus living areas.

Figure 10. Sub-dimensions and indicators for infrastructure dimension

Figure 10 presents four sub-dimensions. Effective Communication and Integration includes indicators related to the interoperability and interactive communication of technologies and software. Innovation covers efforts to follow current technologies and ensure their continuity. Sustainability and Open Access highlight practices such as implementing sustainable solutions, digital and green campus initiatives, and integrating platforms with the TÜBİTAK Harman Open Archive System. Finally, Hardware and Software Accessibility addresses meeting institutional needs for hardware and software, maintaining and updating existing systems, expanding computer laboratories and internet access, and providing software and equipment to support faculty and student research.

The final DMM for higher education comprises five dimensions, 19 sub-dimensions, five maturity levels, and 104 indicators. Figure 11 summarizes the findings for the first research question.

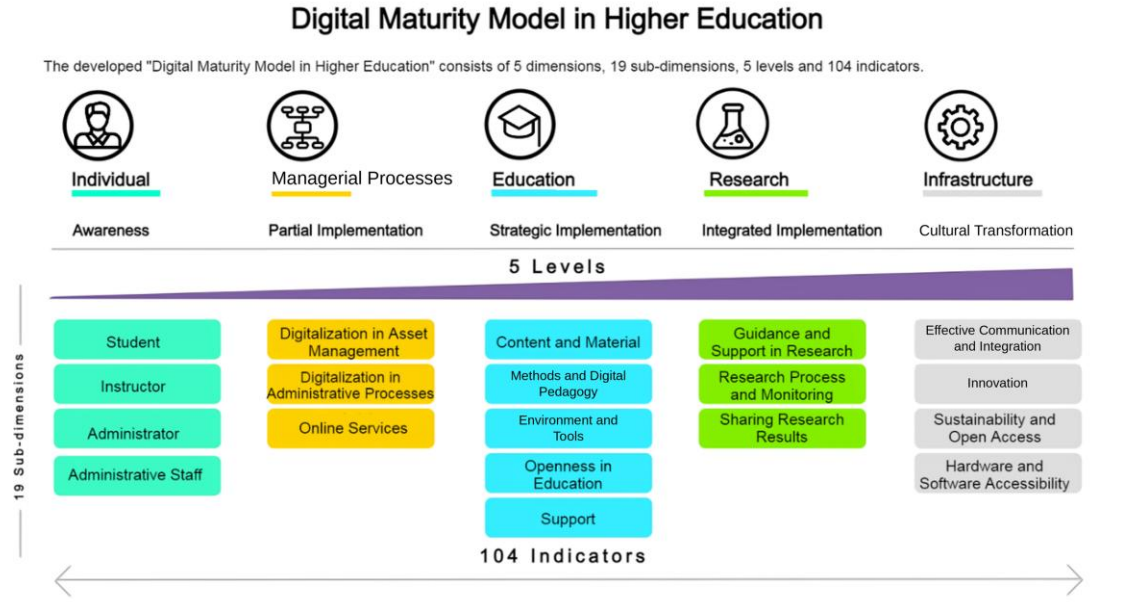


Figure 11. Summary of DMM in higher education

RQ2- Design Principles of DMM in Higher Education

The design principles were identified based on the DMM development process in higher education. Design principles provide guidance for developing a model in a systematic and goal-oriented manner. Four primary design principles and 11 associated sub-principles were identified through iterative content analysis of the interview data, expert-panel notes, and pilot feedback. The resulting codes were grouped into categories and synthesized into broader themes representing the final design principles, which are presented below.

2.1. Holistic Dimensions

The dimensions identified in the model highlight the need for a holistic approach that integrates multiple aspects of digital transformation. Models that focus primarily on individuals, processes, or technology may overlook other important areas of digital transformation. In higher education, organizational and infrastructural dimensions should be considered alongside the sector's core missions of education and research. Participants therefore emphasized the need to define dimensions that combine broader sectoral approaches with universities' core missions. Relevant participant excerpts follow.

> *"Technology-oriented approaches are generally adopted in digital transformation. However, digital transformation goes beyond technology. Therefore, the dimensions should be determined from a holistic perspective rather than focusing on a single aspect." [EPP: EP6]*

This view supports a holistic approach in which the core missions of higher education are considered alongside broader organizational and technological dimensions.

2.2. Clear and Unambiguous Maturity Levels

A key design principle emerging from the study was the need for clear and explicit definitions of maturity levels. The maturity levels should be clearly defined and supported by explanations and examples. Panelists emphasized that clear distinctions between levels would facilitate consistent decision-making when applying the model.

> *"How do we determine whether a particular situation represents Awareness or Partial Implementation? Since there is no quantitative indicator, it may be difficult to decide which level an indicator corresponds to. For example, if every unit implements a particular practice once, would that be sufficient to classify it as Integrated Implementation?" [Pilot Program: Pilot University Participant 5]*

As reflected in the participant's opinion, levels should be defined clearly and understandably, supported by explanations and illustrative examples. Providing sample applications for each level was noted to facilitate decision-making. The panel also considered whether the levels should be qualitative or quantitative and whether the model should comprise three, four, five, or more levels. Participant views on the appropriate assignment of levels are presented below.

> *"Rather than using terms such as inadequate, non-existent or zero, a term such as awareness would be more appropriate because it avoids characterizing universities in negative or deficit-oriented terms." [EPP: EP6]*

The panel ultimately agreed on five qualitative levels and favored non-deficit labels such as Awareness rather than terms such as None or Zero. More broadly, the findings suggest that maturity levels should be clearly differentiated, appropriately labeled, and supported by sufficient guidance to facilitate consistent interpretation.

2.3. Appropriate Level of Indicator Concreteness

A key insight was that indicators should be sufficiently comprehensive without becoming overly detailed. Excessive specificity may substantially increase the number of indicators and reduce usability, whereas overly broad indicators may provide insufficient guidance. Achieving an appropriate level of concreteness therefore emerged as an important design principle. Selected participant views illustrating this point are presented below.

> *"...Therefore, indicators should be simple enough for the university to understand, broad and comprehensive enough to include different practices, and concrete enough to guide them and tell them what to do." [EPP: EP1]*

Participant feedback similarly emphasized the need to balance comprehensiveness and specificity so that indicators remain applicable across different institutional contexts. The findings also showed that indicators must be expressed clearly and understandably. An illustrative participant view is presented below.

> *"The meaning of each indicator should be made clear. Some indicators need to be written more clearly. Otherwise, different meanings may arise. Maybe examples can be given for this. Maybe explanations can be given in the guide." [PP: PUP18]*

Participants also emphasized that indicators should be clearly worded and supported by sufficient explanation to minimize ambiguity. Explanations and illustrative examples were therefore considered as possible ways of improving their interpretability. Participant views on this are as follows.

> *"While giving the indicators under the relevant dimension, a one-paragraph explanation should be prepared to explain that section. Otherwise, what the indicators serve will not be fully understood. It is even useful to support the explanations with examples." [EPP: EP5]*

Expert panelists stressed that each model dimension should include clear explanations to support usability. Participants expressed differing views on the use of examples: some considered them helpful guidance, while others cautioned that they could constrain interpretation. A related participant quotation is provided below.

> *"Examples given with explanations may be perceived as limits, and universities may then evaluate themselves only within the framework of these examples. This could create problems in universities with different practices. I felt that some explanations are needed for guidance. Could the number of examples be increased?" [PP: PUP25]*

The expert panel therefore favored using examples selectively within broader explanatory notes rather than attaching an example to every indicator. Opinions also differed regarding the placement of examples, with some participants preferring them directly under the indicators and others favoring their inclusion within the explanatory notes. Relevant participant quotations are presented below.

> *"It is appropriate to give examples together with the indicators, because practitioners may not read the explanations. It is also difficult to find examples for each indicator, and doing so would lengthen the model. There are advantages and disadvantages to both approaches." [PP: PUP31]*

Although some participants preferred examples to be presented directly alongside indicators for ease of reference, the expert panel raised concerns that this approach could make the model unnecessarily lengthy and encourage overly narrow interpretations.

> *"Providing an example for every indicator may lead practitioners to focus on whether that specific example is present or absent, thereby influencing their assessment. It is also difficult to provide an appropriate example for every indicator. Therefore, it may be preferable to present examples collectively within the explanatory section." [EPP: EP1, EP6, EP7]*

Based on participant feedback and expert-panel discussions, examples were ultimately incorporated into the explanatory sections rather than presented alongside individual indicators, and this was adopted as a design principle in model development.

2.4. Applicability of the Model Structure

The fourth design principle concerns the practical applicability of the model. Findings indicated that applicability depends not only on the model structure itself but also on providing

sufficient guidance to support its implementation across higher education institutions. Accordingly, participants emphasized the importance of developing an implementation guideline to support institutions in interpreting and applying the model.

> *"We need to prepare an implementation guideline that informs universities about the model and provides a conceptual framework supported by methods. The guideline will support institutions with examples and explanations." [EPP: EP1]*

Participant views indicate that preparing an implementation guideline is essential to explain the model and support its use. The guideline should include visuals, examples and a glossary to clarify concepts. Participants also identified digital implementation as a potential means of enhancing the model's applicability, particularly through an interactive system capable of providing institutional feedback. A related participant opinion is presented below.

> *"In the future, it can be transformed into a digital system. It can be transformed into a system that gives automatic feedback to universities that have completed the model, saying that you should improve the following indicators in the next three years." [PP: PUP8]*

Participant feedback suggested that future digitalization of the model could enhance its usability by enabling institutions to receive automated feedback and identify areas for further development.

As a result, various experiences were gained during the model development process. Based on these experiences, a set of design principles was developed to guide model developers. The design principles prepared in this context are summarized in Figure 12.

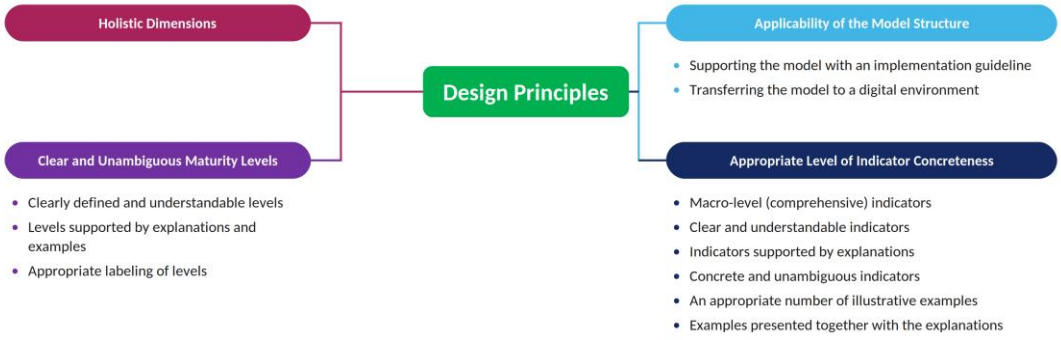


Figure 12. Design principles for developing a digital maturity model in higher education

Discussion

This study aimed to develop a digital maturity model for higher education and identify the design principles emerging from the model development process. Beyond confirming individual model components against prior literature, the present findings carry a more integrative theoretical implication. Existing maturity models in higher education, such as DigCompOrg (2015) and the Jisc (2019) digital capability framework, offer valuable conceptual maps but largely operate at a descriptive level, cataloging relevant organizational elements without translating them into a staged, indicator-based architecture that institutions can act upon. The dimensions, levels, and indicators developed in this study converge with these frameworks conceptually yet diverge from them structurally: by embedding qualitative maturity levels and indicators within an integrated five-dimension architecture, the model conceptualizes digital maturity as an institution-wide capability developing across interrelated

domains rather than as a checklist of technological features. This distinction matters analytically because it shifts the unit of assessment from isolated practices to the coherence between domains; for example, strong infrastructure may not necessarily indicate institution-wide digital maturity when readiness in other dimensions remains limited. In this sense, the findings reinforce a systemic view of digital transformation in higher education, in which maturity depends on development across interrelated institutional domains rather than the accumulation of isolated digital practices.

DMM in Higher Education

The model includes five dimensions (Individual, Managerial Processes, Education, Research and Infrastructure) which align with universities' core missions of education and research (Brundenius & Göransson, 2011; Scott, 2006) and reflect expectations that digital transformation spans these areas (Alenezi, 2021). The Individual dimension highlights human capability, often overlooked in technology-centered models (Egloffstein & Ifenthaler, 2021; Parker, 2020). The Managerial Processes dimension addresses the coordination of institutional processes associated with digital transformation (Matkovic et al., 2018; Seres et al., 2018). Education covers digital teaching and assessment (DigCompOrg, 2015; Üstün et al., 2026), while Research reinforces universities' knowledge-production roles (Kurnaz, 2010). Infrastructure underpins all dimensions, encompassing IT systems, platforms, and campus operations (Jisc, 2019; Parker, 2020).

Taken together, these five dimensions suggest that digital maturity in higher education should be understood as an institutional capability rather than merely a technological condition. From this perspective, digital transformation involves the development of human competencies, organizational governance, educational practices, research capacity, and technological infrastructure. Accordingly, the framework emphasizes the interdependence of these dimensions rather than treating them as isolated components.

The second component of maturity models concerns levels of progression (Redep et al., 2017). This study proposes five levels (Awareness, Partial Implementation, Strategic Implementation, Integrated Implementation, and Cultural Transformation). Awareness reflects minimal engagement and parallels initial stages in prior work (Kane et al., 2017). Partial Implementation denotes unsystematic practices (Wernicke et al., 2021). Strategic Implementation captures systematic, institution-wide efforts and aligns with intermediate or strategic phases (Gökalp et al., 2017). Integrated Implementation shares features with the managed or optimized stages described in previous models (Balaban et al., 2018). Cultural Transformation represents organization-wide digital culture (Ganzarain & Errasti, 2016). Some frameworks also employ quantitative scales (Schumacher et al., 2016).

Rather than representing isolated stages, these maturity levels describe a progressive process of institutional digital development. The levels represent progression from fragmented and technology-focused initiatives toward greater institution-wide integration, culminating in the embedding of digital transformation within organizational culture. Therefore, maturity should be interpreted as a continuum of organizational development rather than a simple checklist of technological adoption.

Indicators are a key component of maturity models, guiding assessment of institutional digitalization (Safiullin et al., 2019; Zamaslo et al., 2021). This study identified 104 indicators across five dimensions. Individual indicators focus on digital competencies and change readiness, consistent with DigCompOrg (2015) and Safiullin et al. (2019), as well as calls to

reduce resistance and provide training (Ae-MoYS, 2011; Balula et al., 2019; Gökşen & Gökşen, 2021). Managerial Processes include data-driven management, transparency and digitized services, paralleling planning, integration and analytics use (DigCompOrg, 2015; Safiullin et al., 2019; Seres et al., 2018). Education covers digital teaching, online environments, content and open resources (DigCompOrg, 2015; FCMM, 2010; HEInnovate, 2013; Safiullin et al., 2019). Research indicators address digital research capacity, collaboration and project support (DigCompOrg, 2015; European University Association, 2015; Finne, 2011; Safiullin et al., 2019). Infrastructure encompasses IT systems, platforms, integration, smart campuses and security, aligned with DigCompOrg's emphasis on availability, access, support and legal compliance (DigCompOrg, 2015; Đurek et al., 2018; Egloffstein & Ifenthaler, 2021).

Collectively, these indicators were designed to capture both the technical and organizational dimensions of digital maturity. Rather than measuring technology adoption alone, they are intended to capture institutional readiness, governance capacity, educational innovation, research capability, and infrastructure within an integrated framework. This structure provides a basis for multidimensional evaluation of universities' digital transformation processes.

DMM in Higher Education Design Principles

Design principles can provide methodological guidance for the systematic development of maturity models (Becker et al., 2009). This study identified principles across four domains (dimensions, levels, indicators, and model structure). The literature offers multiple approaches, including basic–descriptive–normative principles (Pöppelbuß & Röglinger, 2011), staged development processes (Becker et al., 2009; Mettler, 2011), and multi-dimensional frameworks (De Bruin et al., 2005). Consistent with Fraser et al. (2002), a key principle is adopting holistic dimensions that combine organizational, infrastructural, and process elements with higher education missions to ensure contextual relevance. Scope definition through comparison with existing models is similarly emphasized (Becker et al., 2009; De Bruin et al., 2005). Clarity in level definition is also critical, as levels must be explicit, distinct, and supported by examples to ensure reliable assessment (De Bruin et al., 2005; Maier et al., 2009). Five-level structures have been used to balance simplicity and differentiation (Fraser et al., 2002; Mettler, 2011). Although qualitative scales dominate, some studies advocate blended approaches (Kupriyanova et al., 2020). Indicators should be clear, concrete and sufficiently comprehensive without over-specification (Lehmkuhl et al., 2013; Maier et al., 2009). Finally, model usability may also be supported by clear implementation guidance and, potentially, digital tools such as online self-assessment systems (Becker et al., 2009; Pöppelbuß & Röglinger, 2011; Wißotzki & Koç, 2013).

Although the present study did not examine relationships between maturity levels and institutional performance, establishing the model provides a basis for such investigation. By developing and piloting this framework, the present study provides a basis for future research examining relationships between digital maturity and outcomes such as student achievement, research capacity, organizational efficiency, and innovation. This sequencing, which prioritizes model development and refinement before outcome-based testing, is consistent with established model development literature (Pöppelbuß & Röglinger, 2011). Future longitudinal and correlational studies could examine how digital maturity relates to institutional outcomes over time.

Taken as a whole, the design principles identified in this study contribute to maturity model literature beyond their immediate methodological function. Prior work has largely treated

design principles as procedural guidance for model developers (Becker et al., 2009; Pöppelbuß & Röglinger, 2011), specifying how a model should be built rather than why particular design choices affect its downstream validity. The findings also suggest that principles such as indicator specificity and level distinctiveness may support more consistent institutional self-assessment by reducing ambiguity in the interpretation of indicators and maturity levels. When indicators are overly broad or maturity levels are insufficiently differentiated, greater interpretive demands may be placed on assessors, potentially reducing consistency across applications. Viewed in this way, the design principles may offer guidance beyond the development of the present model by highlighting features that should be considered when designing interpretable and practically applicable maturity models.

Conclusion

A DMM for higher education was developed, comprising five dimensions (individual, managerial processes, education, research, and infrastructure) and 19 sub-dimensions covering stakeholders, digital management, pedagogy, research processes, integration, innovation, sustainability, and technology accessibility. The model also includes five maturity levels (awareness, partial implementation, strategic implementation, integrated implementation, and cultural transformation) and 104 indicators. The model is designed to provide a comprehensive framework for assessing digital maturity in higher education, supported by explanations, examples, and an implementation guideline. The findings emphasize the importance of a model that is comprehensive, clearly structured, sufficiently concrete, and practically applicable. The development process yielded four guiding principles: holistic dimensions, clear and unambiguous maturity levels, an appropriate level of indicator concreteness, and practical applicability of the model structure.

Beyond methodological and institutional contributions, the model may also have broader social implications. By supporting institutions in identifying and addressing gaps in their digital capacity, its application may contribute to more accessible and inclusive digital learning environments and greater opportunities for participation in research, innovation, and digital knowledge production. More broadly, strengthening institutional digital maturity may support universities in responding to changing societal and workforce expectations and in contributing to wider digital transformation goals. In this respect, the model may provide a useful framework for aligning institutional digital transformation efforts with higher education's broader societal roles in inclusion, resilience, and innovation.

Suggestions

The study's findings can guide model developers, researchers, and higher education institutions in applying the proposed framework. Future research could explore developing the model into a digital system capable of providing automated feedback and further evaluate its use as an assessment instrument. In addition, the design principles should be further validated through collaboration with maturity model users and developers from both academia and industry. Universities are encouraged to implement the model periodically and involve stakeholders with diverse institutional roles and experience to ensure comprehensive and reliable assessments.

For practical implementation, institutions may integrate the model into existing planning and governance processes to reduce administrative burden and encourage stakeholder engagement.

From a practical perspective, the proposed model may help higher education institutions

identify strengths and areas for improvement across different dimensions of digital maturity, monitor digital maturity over time, and inform strategic planning and resource allocation. The model may also contribute to quality assurance and accreditation processes by providing a structured approach to assessing institutional digital readiness and identifying priority areas for continuous improvement.

Limitations

This study has several limitations that should be considered when interpreting its results. The relatively small number of experts and institutions involved in the development and pilot implementation may limit the transferability of the findings. In addition, all interviews were conducted online, which may have limited the depth of interaction between the researchers and the participants. The use of specific administrative units as indicators within the Managerial Processes dimension may also limit the model's transferability to institutions with different organizational structures. Future research could examine more process-oriented indicators to enhance cross-institutional applicability.

Declarations

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Ethics Statements:

Ethical approval for this study was obtained from the Atatürk University Social and Human Sciences Ethics Committee, Educational Sciences Unit (Meeting No: 02, Decision No: 02, dated 03 February 2022).

Conflict of Interest:

This research has no conflicts of interest.

Informed Consent:

Informed consent was obtained from all individual participants included in the study.

Data availability:

The dataset is available from the corresponding author upon request.

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