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Alignment of University Competencies With Global Skill Measures:

Implications for Education 4.0 in Saudi Arabia as a Case Study

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ABSTRACT

This study analysed two internationally recognised measurements of professional skills: the Programme for the International Assessment of Adult Competencies (PIAAC) and the Digital Competence Framework for Citizens (DigComp 2.2). This analysis aimed to establish a baseline and reference point for a comprehensive understanding of these two scales with the objective of exploring the most relevant competencies and assessing their potential benefits in fostering a technology-driven environment in higher education institutions in Saudi Arabia. The research yielded significant findings regarding the essential competencies that university students should possess, drawing insights from the two assessments and identifying gaps in existing manuals. The research outcomes include valuable insights and best practices that can empower a new generation of university learners to effectively engage with the requirements of Education 4.0.

KEYWORDS

Competencies, DigComp 2.2, PIAAC, University Learners, University Manuals, Vision 2030

The exploration of widely used surveys and internationally recognized frameworks is crucial to help students as they develop the necessary cognitive and metacognitive skills and competencies to become lifelong learners. The surveys also demonstrate how students can be assessed and assisted at different experience levels. This research seeks to explore the interplay between the Programme for the International Assessment of Adult Competencies (PIAAC) and the Digital Competence Framework for Citizens (DigComp 2.2) to identify competencies recommended for learners at Saudi universities that will establish effective problem-solving skills in technology-rich environments. The PIAAC survey is used to analyze skills among adults at various locations, including in their homes,

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at work, and in the broader society (Organization for Economic Co-operation and Development [OECD], 2012). It was initiated by the OECD, which seeks to establish an overarching framework for international skills assessments in multiple countries. The international survey of 24 countries measures the key cognitive and workplace skills of adults aged 16 to 65 to explore how various skills are distributed, why skills are essential, and what factors relate to skill development. It assesses literacy, numeracy, problem-solving in technology-rich environments, and the ability to use information from texts. The United Nations Educational, Scientific, and Cultural Organization developed DigComp 2.2 (Carretero et al., 2017), which maps out four broad proficiency levels: foundation, intermediate, advanced, and highly specialized. It pays more attention to assessing digital competence and lifelong competencies for the learning environment, participation in society, and work activities. The framework includes 21 sub-competencies in five main categories: (a) knowledge about information, (b) communication and collaboration, (c) content creation (including programming), (d) safety (including digital well-being and cybersecurity), and (e) problem-solving and critical thinking.

The PIAAC survey and DigComp 2.2 are perceived as complementing, rather than contradicting, each other to provide more insights and details regarding the combination of knowledge, skills, and attitudes. In other words, they are composed of concepts and facts (i.e., knowledge), descriptions of skills (i.e., the ability to carry out processes), and attitudes (e.g., a disposition/mindset to act). They also represent a fair interaction between vital aspects of life (that is, between digital and non-digital competencies, e.g., between numeracy and cybersecurity). In the current research, the interaction between the PIAAC and DigComp 2.2 results in constructive outcomes regarding essential competencies of 21st-century university learners, and content and courses are suggested for further consideration to meet the needs of the labor market and increase employment opportunities. In addition, the two components strongly intersect with the objectives of Saudi Vision 2030 and its associated principles and initiatives, particularly the Human Capability Development Program (HCDP), as shown below. This research aims to thoroughly examine the development and assessment of digital and lifelong skills in Saudi Arabia, utilizing PIAAC and DigComp 2.2 as guides.

The goal is to identify effective methods for learners to track their progress regarding enhancement of key aspects of human capital within their local contexts. Therefore, this research attempts to answer the following research questions:

RQ1). What competencies are recommended for learners to create effective problem-solving, technology-rich environments?
RQ2). Based on PIAAC and DigComp 2.2, to what extent are digital skills and their associated competencies encountered by university students in Saudi Arabia for effective problem-solving in technology-rich environments?
RQ3). What are the best practices related to the implementation of PIAAC and DigComp 2.2 in Saudi Arabia among university students?

LITERATURE REVIEW

The PIAAC and DigComp 2.2 Frameworks

This research considers two prominent components for measuring skills and digital capabilities among individuals. The first is the PIAAC framework, which encompasses collecting information from adults across three domains to report on educational achievement and work experience. The PIAAC framework has been used by individuals to reach desirable skills in numeracy and literacy (Rammstedt et al., 2017). According to Maslov and Zhong (2022), the comprehensive PIAAC survey provides policymakers with statistics related to education, training, and employment

that enable them to make decisions. In brief, it is a survey designed to measure skills, skill uses, and tasks required in a specific profession. It allows the surveyors to understand whether an individual's skills are sufficient to cope with more demanding duties and whether they need further training to perform their present duties. Thirty-three countries participated in Round 1 of the program between 2008 and 2013 and in Round 2 between 2012 and 2016 (Kawaguchi & Toriyabe, 2022).

As noted by Maslov and Zhong (2022), the survey considers how modern technology can help individuals as they acquire and evaluate information, communicate with others, and solve various types of problems. It comprises three main dimensions. The first is the tasks and problem statement dimension, which includes situational elements that trigger problem-solving, like directions or instructions. These elements are responsible for supplying better problem-solving skills to differentiate between various learning tasks. The second dimension is technologies, including laptop computers, simulated software applications, commands and functions, and representations (such as text and graphics). These technologies assess an individual's ability to use technology effectively to access information, communicate with other individuals and teams, and manage their own learning. The third is the cognitive dimension, which deals with the mental structures and processes used to solve problems. These include setting goals and monitoring progress, planning, locating, selecting, evaluating, organizing, and transforming information.

The other key framework is DigComp 2.2, which provides a common language to identify the key areas of digital competence. It also presents a set of tools that enables educators, trainers, and learners to share an understanding of what constitutes digital literacy and how it can be mapped into different educational practice contexts (Lucas et al., 2022). This framework has been used predominantly throughout Europe to improve citizens' digital competence, help policymakers formulate policies that support digital competence, and plan education and training initiatives to improve the digital competence of specific target groups. Version 2.2 of this framework consists of an update in knowledge, skills, and attitude examples. According to Vuorikari et al. (2022), DigComp 2.2 contributes to a shared understanding of what digital competence involves, including examples of knowledge, skills, and attitudes that help individuals engage confidently, critically, and safely with digital tools. In other words, it shows how to acquire additional digital competence and metacognitive skills, as these are necessary for more effective multidimensional knowledge and multifaceted experiences. It details problem-solving, information and data literacy, digital content creation, communication and collaboration, and safety skills. This helps individuals become more adaptable to 21st-century skills—including becoming tech-savvy, which involves analyzing data and information, developing problem-solving strategies, evaluating solutions, and strengthening communication skills (Szabo et al., 2020).

Education 4.0 and Vision 2030

Adapting these survey and framework components is vital, as Cullinan et al. (2021) reported that one in six higher education students was at risk of lacking the basic knowledge to deal with information and communication technologies. The students in that study confirmed that they had a limited understanding of various technological tools and restricted knowledge regarding the best practices for using the internet and social media. Park and Weng (2020) emphasized the importance of providing appropriate training and well-structured professional programs to assist learners in gaining the digital competence needed to reach academic achievement and successful implementation of Education 4.0.

Education 4.0 is a learning phase related to the fourth industrial revolution that focuses on transforming education by integrating advanced technologies and automation. Education 4.0 encourages building competencies to develop creative and innovative skills, including critical thinking and entrepreneurship, that are necessary for success in today's global economy (Ramírez-Montoya et al., 2022). Furthermore, Education 4.0 deals with individuals' emotions and creative

moral dilemmas and embeds emerging technologies within the physical environment (Bonfield et al., 2020). It also promotes the life skills necessary to ensure individuals' preparedness for future jobs, including reasoning, flexibility, analytical thinking, leadership, resilience, and advanced digital expertise.

In line with Education 4.0, Saudi Vision 2030 has concentrated on meeting the demands and objectives of such education. Using different modes of learning like hybrid and e-learning, the vision aims to produce qualified graduates who can contribute to and help develop a thriving society and a prosperous economy (Kingdom of Saudi Arabia, 2016). To shift from an oil-driven economy toward a more sustainable green economy in which sustainable development goals can be sufficiently achieved, the vision invests heavily in human capital and building the capabilities of individuals, in addition to establishing world-class universities, technology parks, and research centers (Siddiqi et al., 2022). The vision emphasizes the development of the workforce of teachers and learners and their environments to prepare them to master the essential hard and soft skills to become more aligned with labor market needs in the twenty-first century (Grand & Wolff, 2020). This has resulted in a tremendous movement toward updating standards, policies, and regulations, empowering the private sector, and designing more appropriate training. These training programs have become more focused on meeting both labor and skill shortages. In 2021, the International Labour Organization drew attention to the importance of the skilling, reskilling, and upskilling that individuals need as they move from one job to another; these advances promote individuals' lifelong learning practices, social inclusion, active citizenship, and personal development. Because of the ambitions of officials to implement digital transformation, the adoption of both the PIAAC and DigComp 2.2 has become vital to create more problem-solving and technology-rich environments in other European contexts.

The HCDP and National Qualification Framework Initiatives

Saudi Arabia has made substantial changes through its Vision 2030 plan, which includes several initiatives to enhance the skills and potential of its people. The objectives are to decrease unemployment, increase private sector contribution, and diversify the economic base beyond the oil industry. The program represents Saudi Arabia's strategy to strengthen different local and global capabilities by seizing significant opportunities resulting from rapid and renewed worldwide changes. Notable characteristics of this program include 89 initiatives that have helped Saudi Arabia achieve 16 strategic objectives. The strategy is built on three key pillars: the development of a resilient, strong educational base; preparation for a future labor market, both locally and globally; and the provision of lifelong learning opportunities (Rivera et al., 2022). One significant advantage of a knowledge-based economy is that it uses technology for competitive advantage (Siddiqi et al., 2022).

One of the key programs resulting from Saudi Vision 2030 is the HCDP, which contains different strategies designed to boost the talents and skills of Saudi Arabia's workforce. These strategies take various forms, such as professional growth programs, vocational training, and academic courses. The HCDP encourages the implementation of various training methods using digital tools and technology-rich environments to achieve certain objectives. Sansone et al. (2019) established that reflection, research, construction, and technology-mediated strategies can fill the gap between successful training and satisfactory implementation of digital technologies. The implementation of the HCDP is a significant attempt to equip Saudi citizens with the necessary skills to help achieve Vision 2030.

In addition, one of the initiatives within the HCDP is the career guidance initiative, which aims to provide individuals with the appropriate skills to develop their career objectives. The initiative aligns Saudis' educational outcomes with the needs of the private sector, as indicated in the previous section. Algraini (2021) highlights the role of human capability and progress, which is seen as an instrument to promote economic growth and increase personal income. As the HCDP intersects with the strategic goals of the National Qualifications Framework (NQF) initiative, it has become essential to understand its role in Saudi Arabia's educational system and how the PIAAC can be used

as a baseline for the enhancement of digitally supported problem-solving skills among learners. The Education and Training Evaluation Commission (ETEC) has established the NQF as a reference for various educational institutions to identify their students' knowledge, skill sets, and qualifications from childhood to the doctoral level. This will ultimately contribute to the better design of activities and quality assurance. The NQF consists of three main components that specify three learning domains: (a) knowledge and understanding, (b) skills, and (c) values, autonomy, and responsibility. The knowledge and understanding component involves acquiring broad knowledge and comprehending theories, techniques, practices, and research methodologies. The skills component demonstrates the acquisition of three types of skills: cognitive skills, practical and physical skills, and communication and information and communications technology skills.

METHODOLOGY

This research took a qualitative approach in which official documents (handbooks) of three universities located in three major cities in Saudi Arabia were analyzed on the basis of the PIAAC and DigComp 2.2. This analysis sought to explore to what extent they could be used in the local context of Saudi Arabia and how they aligned with internationally accredited frameworks and existing information. The study addressed three vital research questions through reflections and benchmarking and compared Saudi Arabia with other international settings.

This research focused on analyzing the handbooks of the three institutions as primary sources of information to understand the competencies targeted by the institutions. The handbooks offered an official, standardized, and reliable source of each institution's educational policies. They reflected institutional priorities, provided policy guidance, and offered insights into the historical evolution of educational trends in those institutions. Finally, they served as a baseline to understand and compare how each institution's foundational competencies aligned with broader educational frameworks. They were a valuable resource for understanding the learning outcomes and pedagogical approaches within each institutions' educational settings.

Conducting further exploration of stakeholders' perspectives through qualitative interviews or surveys would undoubtedly enrich the analysis by providing a deeper understanding of the subject matter. However, for the purposes of this study, the researchers chose to focus solely on theoretical frameworks as a preliminary foundation for the upcoming research paper. While recognizing the value of the stakeholders' perspectives, the current study aimed to establish a solid theoretical groundwork before expanding into empirical investigations in future research. By focusing on theoretical frameworks in this initial stage, the researchers were able to lay a strong foundation that would inform subsequent stages of the research. This approach enabled a systematic and comprehensive exploration of the conceptual underpinnings before directly engaging with stakeholders. Thus the research provided a comprehensive theoretical framework that can guide future empirical investigations and ensure a robust analysis of stakeholders' perspectives.

FINDINGS

RQ1). What competencies are recommended for learners to create effective problem-solving, technology-rich environments?

In line with the PIAAC and DigComp 2.2 recommendations with regard to reinforcing problem-solving skills in digitally supported environments, this research question touches on major competencies leading to more technologically advanced societies. Both references were used as a benchmark for analyzing the HCDP's key goals and Saudi Arabia's digital transformation strategy to align with other internationally accredited digital competency frameworks. A set of

competencies was identified, and sub-competencies were drawn from the PIAAC and DigComp 2.2. The competencies and sub-competencies were found to complement each other, as shown in Table 1. They focus on the abilities, knowledge, and skills that Saudi graduates need to acquire to be more successful. They are also linked to future work requirements, better preparation for Education 4.0, the development of globally competitive citizens, and greater capability of achieving Vision 2030 and the HCDP's goals. The findings show that learners should have competencies related to various digital tools, platforms, and the internet to enhance productivity and efficiency while considering cyber safety. These competencies include (a) the ability to understand, use, and manage digital technologies; (b) the ability to find, analyze, and use digital information; and (c) the ability to collaborate with others internationally, nationally, and locally to solve problems and provide innovative solutions.

RQ2). Based on the PIAAC and DigComp 2.2, to what extent are digital skills and their associated competencies encountered by university students in Saudi Arabia for effective problem-solving in technology-rich environments?

In addressing this question, it should be noted that the specifications of graduates' competencies in Saudi Arabian universities are aligned with the NQF to guide the national accreditation process. As stated earlier, the researchers chose to analyze the competencies of the students at three public universities in Saudi Arabia because of the availability of their published manuals online, as shown in Table 2.

The analysis of digital skills was based on the proposed framework mentioned in the previous question (Table 1), which is drawn from the PIAAC and DigComp 2.2. Digital skills are explicitly stated in the universities' manuals under different terminologies: technical skills, technological skills, and information technology skills. According to the three institutions that were studied, digital skills represent graduates' abilities to: (a) utilize various types of technologies to provide specialized, functional solutions in their field; (b) contribute to real-world digital development by investing in modern technologies, such as artificial intelligence, programming, and data analysis; and (c) perform numerical operations efficiently. The manuals also promote a high level of proficiency with digital skills to enable individuals to solve ill-structured problems. Digital skills involve using web-based tools and multiple platforms and devices to perform work-oriented tasks. Those tasks might relate to graduates' specific majors; for instance, they might utilize special software to develop solutions. The tasks might also be general tasks associated with management, such as utilizing Microsoft Office tools to perform day-to-day tasks.

This research harmonized with the skills required by the PIAAC because those evolving technologies demand a high level of numerical skill. Therefore, numerical skills can be considered to be complementary to digital skills. The current analysis extracted the skills defined in the manuals, particularly those that were related to digital skills. In line with this argument, the findings demonstrated that the PIAAC-related skills were mentioned in the manuals only to a minimal extent and with insufficient information. The manuals were found to be generally undescriptive and not necessarily focused on digital skills; for instance, two universities mentioned adaptability as a competence for sound digital environments.

The manuals mentioned the role of effective communication, which they described as the ability to communicate with others in physical or virtual environments using oral, written, or digital formats in one or more modern languages. Interestingly, the findings also revealed a massive need to draw attention to the key terms used for the competencies that 21st-century university learners need as part of their professional careers and lifelong learning, including "being creative," "being innovative," "being critical thinkers," and "being problem-solvers." While some variance is acceptable, different terms may not refer to the same set of skills. "Critical thinking: and "problem-solving" are described as the graduates' abilities to apply theories, analyze data, interpret results, and critique solutions to

Table 1. Desired competencies for problem-solving in technology-rich environments

Based on the PIAAC, DigComp 2.2, and HCPD Frameworks		
Competency	**Sub-Competencies**	**Indicators**
Abilities	Adaptability	Definition: The willingness to accommodate the changes in the technology landscape to gain new technological skills with confidence Able to • connect digital knowledge with device-specific knowledge to perform certain tasks • recognize the structure of new software, apps, and websites • explore the functionality of new software, apps, and websites • troubleshoot technical or information problems to meet certain needs
	Creativity	Definition: The ability to use digital tools and technologies to create new ideas and apply different strategies to present output in new forms Able to • utilize brainstorming techniques, prototyping, and other methods to generate ideas • design and develop digital content, services, and processes • leverage emerging technologies, such as AI and big data, to create a personalized user experience • utilize digital technologies and tools, such as 3D printing and programming, to present physical or virtual products in different forms
	Flexibility	Definition: The ability to compromise by scaling IT skills up or down according to the situation's need without altering the overall strategy Able to • switch between remote and non-remote working using digital technologies (hybrid worker) • think and process information accurately to make effective decisions with mental agility • use computers and other digital devices to access information, communicate with others, and complete tasks in an efficient manner • align technology activities across the organization to meet the demand of rapidly evolving technology
	Innovation	Definition: The ability to extend digital creativity to produce new technologies or tools aligned with digital transformation Able to • create unique approaches to using digital technologies and tools to solve problems • utilize computational thinking to solve problems algorithmically and logically • utilize design thinking to create innovative digital solutions • adopt innovative ways to use new digital technologies and platforms for different purposes, including business, educational, and personal
	Leadership	Definition: The ability to lead an organization in digital transformation and be IT enablers Able to • take the lead in best practices for risk management to satisfy the need of the organization and its customers to safely access data • source competencies through partnerships with educational and technology institutions to provide access to in-demand digital skills • encourage cross-training for non-technology specialists to take technology roles in the organization • encourage the acquisition of skills through micro-credential and stackable certificates
Knowledge	Digital Citizenship	Definition: The responsible use of digital technologies, including computers, the internet, and digital devices, to engage in personal and social activities in an ethical manner Able to • apply appropriate verbal and non-verbal expression through understanding distinctions between personal and professional identities • promote a safe and healthy online culture by understanding copyright, privacy, data security, cyberbullying, and ethics • monitor one's digital behaviors, e.g., refrain from cyberbullying • respect privacy and security, e.g., understand the need for security protocols, such as password protection, encrypting data, and avoiding phishing scams
	Digital Literacy	Definition: The intellectual ability to articulate, evaluate, interpret, and effectively use information and technology, consisting of data literacy, information literacy, digital visual literacy, digital media literacy, and metaliteracy Able to • employ effective strategies to search and retrieve data, information, and digital content • use big data sets to make informative decisions by asking critical questions. • evaluate the validity and credibility of data, information, and digital content • create and interpret visual materials produced by digital technologies (digital visual literacy) • utilize metacognition (metaliteracy) to learn and apply what was learned to new situations

continued on following page

Table 1. Continued

Based on the PIAAC, DigComp 2.2, and HCPD Frameworks		
Competency	**Sub-Competencies**	**Indicators**
Knowledge	Interdisciplinary Knowledge	Definition: The ability to combine knowledge and expertise from different disciplines to gain a comprehensive understanding of a problem and create a holistic solution Able to • analyse, evaluate, and synthesize information from multiple sources to make informed decisions • combine components of two or more disciplines in the pursuit or creation of new knowledge, processes, or products • develop a shared understanding among multidisciplinary team members • utilize technologies in sharing and documenting understanding to ensure effective communication and iterative process of engagement
	Digital Security and Cyber Safety vs. Cybersecurity and Cybernetics	Definition: The ability to identify potential online risks and act accordingly through certified protocols and ethical practices to secure personal and institutional data and follow safety measures to avoid cyberattacks Able to • build a positive online reputation by avoiding cyberbullying, plagiarism, inappropriate content sharing, and inappropriate social media use • follow network security measures to protect a network from unauthorized access and malicious threats, such as viruses and malware • utilize an effective authentication process to verify a user's identity before allowing access to digital resources or information • specify access control protocol to limit access to digital resources or information according to specific measures or needs
Skills	Collaboration	Definition: The ability to utilize digital technologies to collaborate with a culturally diverse group of individuals in a respectful manner while maintaining an effective virtual presence Able to • work with others, deal with complex problems, and utilize diverse perspectives • assign tasks to members and keep track of progress with task management tools • monitor team performance and effectively store and share digital materials, such as documents and videos • utilize digital storytelling to communicate new knowledge by choosing the appropriate medium (e.g. virtual reality and augmented reality)
	Time Management	Definition: The ability to efficiently manage time and meet deadlines when using digital technologies and tools to finish required tasks, commitments, or duties Able to • use technologies to manage and track tasks and activities to achieve goals • manage one's time and workload • organize digital content, create a schedule and stick to it, and meet deadlines • use digital project management software to assign and track tasks.
	Problem Solving	Definition: The ability to use digital technologies and tools to identify and analyse problems and develop, evaluate, and implement appropriate solutions. Able to • analyse situations and their possible causes and consequences and develop a plan of action • identify problems, provide solutions, and use logic, reasoning, and critical thinking to resolve issues • test solutions through modelling in a controlled environment and verify results • analyse available resources that could help in solving problems, including Scrum boards, digital documents, and data sets
	Communication	Definition: The ability to effectively convey ideas and information by choosing the appropriate medium and using digital technologies and tools Able to • interact appropriately with others in digital spaces • create effective digital demonstrations, taking into account netiquette • remember, store, and recall information successfully • explain concepts clearly and respond to others' feedback
	Technical proficiency	Definition: The ability to use and operate various digital tools, software, and equipment related to a particular field Able to • create and manage online accounts, interact with stakeholders, and be proficient in various social media platforms • engage effectively with colleagues in virtual environments • assess data, discover patterns, and draw meaningful conclusions • collect, analyse, and interpret data to better understand the problem and find the best solution

Table 2. Details of the three universities included in the study

University	King Saud University (Riyadh)	King Abdulaziz University (Jeddah)	Imam Abdulrahman Bin Faisal University (Dammam)
Establishment Year	1957	1967	1975
Sector	Public	Public	Public
Location	Central region	Western region	Eastern region
# of Students	64,000	117,096	154,432
# of Annul Graduates	10,000	8,110	8,288

make effective decisions that solve complex problems. In technology-oriented environments, those sub-competencies should reinforce the university graduates' skills so they are linguistically and culturally competent with knowledge about technology and are able to effectively utilize digital tools to reach digital transformation and solve emerging problems.

The sub-competencies of flexibility, cyber safety, and interdisciplinary knowledge, and the means of enhancing them, are not presented in detail. Each manual stated at least one technology (e.g., programming) as a core skill to prepare these learners for future markets. Such technologies, as well as the ways they can best be used in virtual environments, should be nurtured and supported through training to satisfy the demands of Education 4.0. Table 3 shows in detail the alignment between the competencies stated in the university manuals and the proposed competencies drawn from the consolidation of the PIAAC and DigComp 2.2.

The analysis has explicitly revealed that rapid technological progress has led national and international universities to integrate new aspects of modern tools with the digital skills that graduates need to be acquainted with before graduation. In Saudi Arabia, where there exists a significant transition toward a knowledge-based economy, most universities have begun to prepare their graduates for unidentified jobs by employing the necessary technologies. This preparation involves dealing

Table 3. Alignment between current competencies (stated in the manuals) and the proposed competencies

Competency	Sub-Competencies	KSU	KAU	IAU
Abilities	Adaptability	Yes	Yes	-
	Creativity	-	Yes	-
	Flexibility	-	-	-
	Innovation	Yes	-	-
	Leadership	Yes	Yes	Yes
Knowledge	Digital citizenship	Yes	Yes	Yes
	Digital literacy	-	Yes	Yes
	Interdisciplinarity knowledge	-	Yes	-
	Cyber safety	-	-	-
Skills	Collaboration	Yes	Yes	Yes
	Time management	-	Yes	-
	Problem solving/critical thinking	Yes	Yes	Yes
	Communication	Yes	Yes	Yes
	Technical proficiency	Yes	Yes	Yes

with AI, robotics, digital fabrication, the metaverse, gaming, blockchain, and data analytics, all of which have begun to reshape the job sector and the relevant skills needed. Those technologies should be adopted by the university curricula to increase employability rates and enhance creativity and innovation. Robotics has become more humanized for real-world situations, and artificial intelligence has replaced many jobs. Digital fabrication has enhanced engineering and related fields, in which rapid and accurate prototypes of designs have become increasingly possible. The metaverse has revolutionized augmented and virtual reality technologies, in which more immersive environments have become a reality, and it has reshaped the nature of gaming, moving it beyond entertainment to serve other purposes, like game-based learning. Blockchain technology has also established innovative business models to decentralize products and services using cloud computing. The need for skills related to cloud computing is rapidly increasing, and new jobs have been created that demand a deep knowledge of data analytics to manage huge amounts of distributed data and make informed decisions.

RQ3). What are the best practices related to the implementation of the PIAAC and DigComp 2.2 in Saudi Arabia among university students?

The third research question addresses suggestions for the best practices to more effectively implement the PIAAC and DigComp 2.2 in relation to Saudi Arabian university learners. Implementing them for higher education students involves understanding the specific needs and challenges these students face. It is crucial to consider integrating these frameworks into the curricula by aligning digital competencies with course objectives and outcomes. Students benefit from seeing the practical applications of their learning, especially when these applications relate to professional or everyday contexts. Assessment and feedback can be valuable so students are able to identify their strengths and their areas needing improvement. A peer learning environment encourages an effective knowledge exchange, which can be particularly beneficial in developing digital competencies. It is also beneficial to utilize these frameworks for the professional development of faculty members to ensure that they can effectively support their students' learning.

In the digital era, it is necessary to provide all students with equitable access to technology and resources to develop digital competencies. Collaboration with industry partners can keep the implementation of these frameworks relevant and aligned with workforce demands. The importance of regular evaluations and updating cannot be overstated; the implementation must remain effective and responsive to student needs. Finally, stressing the role these competencies play in enhancing employability can motivate students, given that the PIAAC and DigComp 2.2 skills are highly valued in today's information-driven, technologically advanced workforce. Implementation should be tailored to the institution and its students' specific needs and contexts. Accordingly, five main practices have been drawn from this comparative analysis and benchmarking. These main practices are as follows:

Practice 1: Understanding Students' Needs

The revealing outcomes of both frameworks help to explain the differences among adults' highest and lowest levels of performance in terms of literacy, numeracy, problem-solving, and adaptive problem-solving. As highlighted by the PIAAC, literacy includes using information from digital texts to develop knowledge. Levels of performance range from foundational to intermediate, advanced, and highly specialized. Conducting a thorough needs assessment to understand higher education students' unique needs and challenges is essential to an effectively implementation of PIAAC and DigComp 2.2. This assessment can be carried out through surveys, focus groups, or personal interviews. Understanding those needs will inform how to implement the frameworks and enable customization according to each degree program. For instance, aligning the DigComp 2.2 competency areas with the specific skills required for each degree program will ensure that the students gain the relevant digital competencies to support their academic progress and future career paths. This approach also

ensures that the frameworks are student centered, relevant, and effective in promoting meaningful learning experiences.

Practice 2: Leveraging Learning Key Components

Both frameworks help to identify the variations within different groups and populations, either from various countries or within the same country. Low-skilled individuals and groups are defined as to whether the disparities are due to age, gender, educational background, employment status, or health issues. For quality control and improvements, the benchmarking of the graduates' competencies should take into account the digital competencies of graduates from other institutions or countries. To enhance the relevance and effectiveness of higher education, it is recommended that PIAAC and DigComp 2.2 should be thoroughly integrated into the curricula—specifically, into course objectives and outcomes. This strategic inclusion of digital competencies in curricula can offer a seamless learning experience and encourage students to develop relevant skills as part of their academic progress. It would be beneficial to collaborate with faculty across various degree programs to ensure that these competencies align with the academic content, making the learning more relevant and engaging for students.

Furthermore, these frameworks should be utilized to create meaningful assessments that can provide valuable insights into each student's strengths and areas needing improvement. Offering formative and summative assessments of students' attainment of such learning outcomes can provide ongoing feedback and final evaluations of students' skills. Personalized feedback based on these assessments can help students understand their current proficiency levels in digital competence and literacy skills and show them the necessary steps for improvement. Finally, an educational environment that promotes peer learning can significantly enhance the acquisition of digital competencies. Through collaborative activities, such as group projects, peer tutoring, project- and problem-based learning, and online discussion forums, students can learn from each other's experiences and utilize problem-solving strategies. This collaborative approach enriches the learning process and fosters a sense of community and mutual support among students, which is invaluable in the educational journey.

Practice 3: Enhancing Employability and Workforce Readiness

Both frameworks help to identify the factors influencing various levels of skill development and those factors' relation to demographic variables. This information could enable individuals to access more skills to enhance their employability and labor productivity. Measurements of graduates' competencies should consider such aspects to investigate factors that can affect the achievement of intended outcomes. Therefore, it is important to emphasize the role of the PIAAC and DigComp 2.2 competencies in enhancing employability as part of the institution's academic guidance and career counseling efforts. These skills are increasingly vital in the modern workforce, and their relevance needs to be highlighted throughout the students' educational journey. Thus, organizing workshops, seminars, and career talks that underscore the importance of these competencies in various professional contexts is critical to students' acquisition of digital skills. Higher education leaders can also coordinate tailored professional programs by inviting industry experts and alumni who can share their experiences and insights on the practical applications of these skills in the workplace. Additionally, they can ensure that these competencies are integrated into coursework and work–study programs, internships, and capstone projects in which students can apply these skills in real-world situations. Finally, it is important to showcase successful alumni who have used these competencies to excel in their careers. These success stories can be powerful examples to current students regarding the potential benefits of mastering the PIAAC and DigComp 2.2 skills.

Practice 4: Ensuring Equitable Access to the Internet and Digital Resources

It is of utmost importance that every single student has fair access to the technology and resources they need to develop the necessary digital skills demanded by the modern world. Assessing students'

digital capabilities and needs is crucial for identifying the challenges they might encounter. Universities must also ensure that campuses are geared toward supporting digital skill development. This effort could involve providing a strong, reliable Wi-Fi network and setting up fully equipped computer labs to guarantee that students have the physical resources they need to develop digital competencies. It is also essential to advocate for policies that ensure that every student has access to high-quality internet and devices and that allocate more resources toward digital equity.

Practice 5: Maintaining Continuous Evaluation

Both frameworks should help to determine the key skills to be attained by university students before graduation through the mapping of these skills to student and program learning outcomes. For instance, "creativity" as a competency should be considered as the ability to generate unique solutions and approaches in technology-based environments. Citizenship should consider best practices to deal with issues in virtual environments, such as copyrights, plagiarism, and cyberbullying. Therefore, continuous evaluation is a crucial aspect of effectively implementing the PIAAC and DigComp 2.2 frameworks in higher education. This process involves the regular collection of student feedback, thorough assessment data analysis, and consistent curriculum reviews to ensure alignment with evolving digital competencies. The role of faculty is integral in this process; their insights based on classroom experiences can offer valuable feedback, and their professional development is key to maintaining effective teaching of these competencies. Benchmarking against other institutions can provide further insights into best practices and potential areas for improvement. Ultimately, continuous evaluation aims to create an iterative process of making improvements and refining teaching methods, resources, and objectives on the basis of consistent feedback and evolving needs. This process ensures the continued relevance and effectiveness of the implemented frameworks while fostering a culture of continuous learning and improvement within the institution.

DISCUSSION AND CONCLUSION

The research findings underscore the value of the key competencies recommended by PIAAC and DigComp 2.2. These important competencies—adaptability, creativity, flexibility, digital literacy, collaboration, effective time management, and problem-solving—are essential for future-ready education and training. While these skills might be familiar and are indeed integrated into some academic programs, there is a notable gap. Although they provide a solid foundation, the current educational manuals often lack the dynamic approach needed to prepare students for the rapidly evolving digital landscape. The power of the PIAAC and DigComp 2.2 key competency recommendations lies in their ability to align educational outcomes with the skills needed for success in a digitalized world. Adapting to this digital transformation is critical, and meeting these competencies is integral to this process. This conclusion is consistent with Tang et al. (2020), who emphasize that these competencies are key to the advancement of Education 4.0 and to the preparation of learners for future job markets and industries, and with Ramírez-Montoya et al. (2021), who assert that strengthening such skills is crucial for devising innovative solutions to the challenges of today's global society. Furthermore, the effectiveness of PIAAC and DigComp 2.2 is shaped by three central domains: authenticity, cultural relevance, and practical real-life situations. These characteristics suggest that the learning experiences designed to develop these competencies should be grounded in authentic contexts, respectful of cultural diversities, and applicable to real-life scenarios. In essence, the development of these competencies should be closely intertwined with the realities surrounding the learners, including their experiences, cultural backgrounds, and future professional challenges.

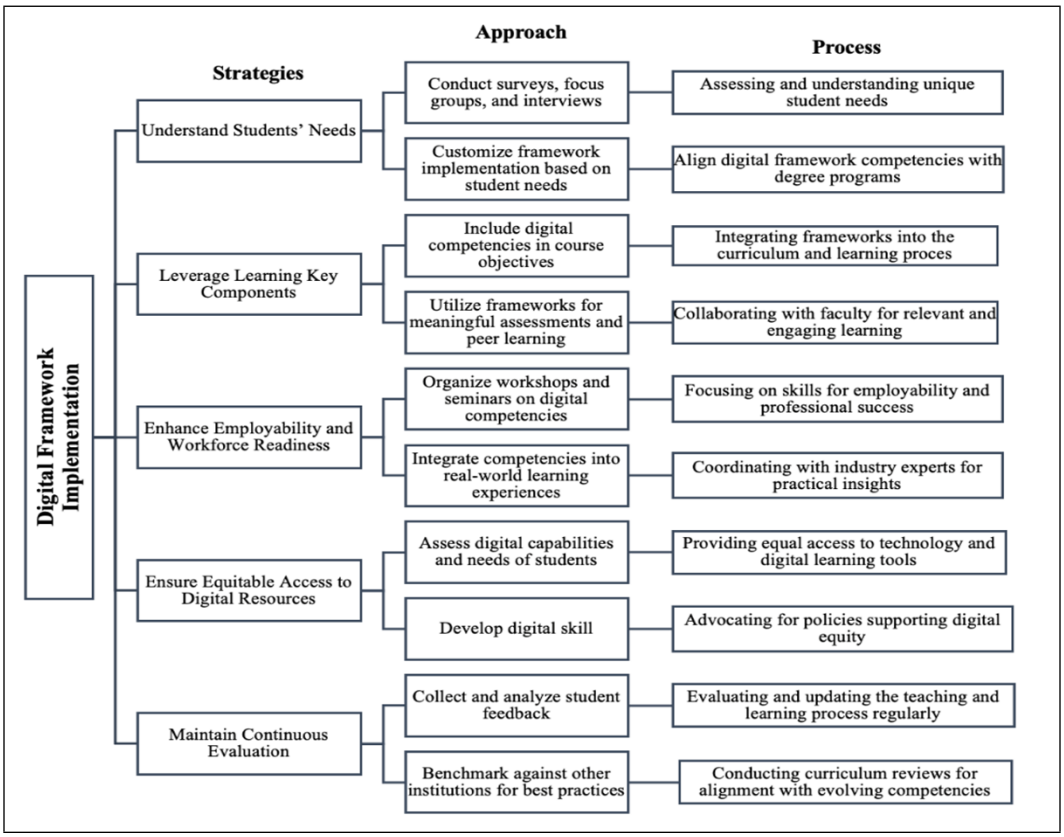
Such competencies and sub-competencies can be successfully reinforced when training programs are designed and become available to educators. The findings have confirmed that implementing them in the local context with Saudi learners would ensure international collaboration and competition. The development of digital competencies has been seen as an effective, positive tool for undergraduate

performance that achieves more sustainable development and organizational readiness (Alotaibi, 2022). Furthermore, Yamani et al. (2021) revealed that there are several digital competencies required by university students, such as dealing with multiple electronic indexing applications and learning management systems, using electronic bibliographic control tools, using artificial intelligence tools, cybersecurity system maintenance, and using various programming languages (e.g., Python), simulation, and augmented reality applications.

The analysis has confirmed that encouraging certain qualities can promote self-employment and develop leadership and entrepreneurship among participants. This training can benefit stakeholders, such as learners, educators, and small enterprise owners, by developing the skills of job seekers and students to meet the requirements of the Saudi labor market. This system has been shown to have an impact on learners internationally, particularly in higher education, in that they gained a better understanding of the foundational skills necessary to develop students' higher literacy and numeracy abilities for a functioning society (Edelmann et al., 2023; Helsinger et al., 2023). They have also paid more attention to the role of assessment and the measurement of skills, which is also highly comparable within and between countries. Those represented lessons and meaningful experiences can be highly effective in the local context of Saudi Arabia. The research has disclosed recommendations regarding effectively integrating PIAAC and DigComp 2.2 as primary assessment tools in the education system to ensure that learners are fully prepared for emerging technologies. Table 4 shows in practical steps how this alignment could be achieved through three main stages: strategies, approaches, and processes.

Regarding the limitations of the study, the research has investigated manuals of only three public universities. Using manuals from additional colleges and universities, including public,

Table 4. Alignment between various stages of digital framework implementation



private, historical, and modern institutions, might reveal more findings. Notably, the King Abdullah University of Science and Technology and the Prince Mohammed Bin Salman College of Business and Entrepreneurship are both highly focused on PIAAC and DigComp 2.2 skills, in addition to leadership, innovation, and other industrial revolution skills. Furthermore, the current research has used secondary data. It would be very interesting to seek further qualitative and quantitative data from stakeholders concerning their knowledge, experiences, perspectives, and expectations about PIAAC and DigComp 2.2.

This research focuses on analyzing the handbooks of three institutions as a primary source of information to understand the competencies targeted by the institutions under discussion. Future studies can involve empirical studies to measure the actual learning outcomes and how they correlate with PIAAC and DigComp 2.2 competencies. Further case study analyses can be conducted within academic units to observe competency implementation and perform longitudinal studies to track competency development over time. Additionally, comparative analyses across different institutions that integrate external feedback from industry professionals, examine the impact of technology-enhanced learning, analyze and revise curricula, and explore cross-disciplinary competency development are valuable areas for further investigation. As stated previously, the key objective of this research was to develop an innovative and comprehensive conceptual framework that encompasses the competencies required to thrive in the Education 4.0 era. The paper provides a detailed analysis of these competencies, which are categorized into two components aligned with well-defined frameworks: digital competence skills and complex thinking skills. These competencies aim to enhance learners' lifelong learning journey. To further strengthen the study, the researchers plan to expand institutional engagement in the future stages of the research. This expanded engagement will allow for a more comprehensive understanding of the topic by incorporating insights and perspectives from a wider range of institutions. The researchers recognize the importance of this engagement in enriching the study's findings and ensuring their relevance to real-world educational contexts. Although the selected institutions represent the largest sample size available in this study, it is important to note that the researchers acknowledge the need to expand the sample size in future research. The upcoming stages of the future research paper will delve into additional institutions in detail to address this limitation.

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