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Learning technologies and professional competence development for future IT specialists in the context of sustainable development

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Abstract. The aim of the study was to examine the tools and technologies used in the educational programmes of leading technical universities in Ukraine to train future IT specialists. The research methodology included a survey of 312 students and 28 lecturers, an analysis of digital platforms and technologies, as well as a comparative analysis of the effectiveness of the tools used to develop the professional competence of future IT specialists in the context of sustainable development. The study examined the impact of modern digital technologies on the development of professional competence of future IT specialists. The active use of platforms such as GitHub, Moodle, Cisco Networking Academy, and cloud tools confirmed a positive impact on the development of practical skills and critical thinking. The study found that 89 students recognised these technologies as effective for professional growth. More than 176 respondents participated in projects that incorporate the principles of sustainable development, indicating the integration of environmental and ethical aspects into the learning process. In addition, 167 students noted the effectiveness of online courses on the Coursera and edX platforms for in-depth study of the material, which increases their competitiveness. Analysis of the results showed that services such as GitHub, Docker, AWS Educate, and Cisco Networking Academy play a key role in shaping practical, project-oriented skills. On the other hand, learning management tools such as Moodle and Microsoft Teams have a different functional purpose and are used primarily for communication, learning material management, and educational environment support, rather than for developing applied technical competencies. The practical significance of this work is that it can be used by lecturers, educational institutions, and curriculum developers to improve the training of IT specialists by integrating modern digital tools and technologies into the learning process, taking into account the principles of sustainable development

Keywords: educational process; training of specialists; innovative technologies; programming process; practical skills

INTRODUCTION

The relevance of the research topic was determined by transformational processes in education and the growing requirements for the content and forms of organisation of professional training. Contemporary changes in the higher education system include the integration of new digital technologies, the modernisation of teaching methods, and the renewal of approaches to training specialists in Field F "Information Technologies" (in particular areas F1-F7, among which F1/121 "Software Engineering" is of particular importance). This creates the need to develop future IT specialists' ability to work with modern information systems, apply data analytics, and design and implement innovative technological solutions that meet the current needs of the IT sector. However, at the present stage of educational science development, there is still a lack of systematic research into how innovative educational technologies can

be integrated into the training of IT specialists specifically with regard to the principles of sustainable development. The absence of clearly defined methodological approaches to combining professional training with the ideas of sustainability hinders the holistic development of such qualities among students as environmental awareness, social responsibility, critical thinking, and the ability for interdisciplinary interaction. In addition, there was a shortage of empirical studies that would make it possible to substantiate the effectiveness of particular didactic models, digital platforms, or project-based learning methods in the development of sustainable professional competencies.

A number of researchers have examined various aspects of training future IT specialists. In particular, Y. Tryus & I. Herasymenko (2021) analysed approaches, models, methods and tools for training future IT specialists using elements of dual education. They demonstrated the effectiveness of combining academic learning with practical experience, which contributes to better adaptation of students to the needs of the IT market. M. Váraljai *et al.* (2024) explored the possibilities of shaping students' thinking through the implementation of innovative IT tools and project management technologies in higher education. The authors substantiated the need for flexible digital solutions that ensure the adaptability of the learning process to contemporary requirements. V. Yunchyk *et al.* (2021) proposed a cognitive model of the IT specialist training process that takes into account the specific features of students' perception and information processing. The model made it possible to formalise educational activities and adapt curricula to the cognitive characteristics of learners. L. Pavlenko & M. Pavlenko (2024) examined augmented reality tools as a component of a modern educational environment for IT specialists. The researchers demonstrated that AR technologies significantly enhance the visualisation of abstract concepts and contribute to deeper learning. A practice-oriented approach to training IT students through the use of virtual reality in the field of programmable logic controllers was proposed by K. Kubola *et al.* (2022). They showed that VR tools make it possible to create a safe, cost-effective and realistic environment for practising technical skills. O. Markova & M. Marienko (2021) investigated the use of cloud-based workshops in the training of future IT specialists, confirming that such workshops enhance flexibility, accessibility and students' technological literacy. O. Karupu *et al.* (2021) proposed a model for developing the professional skills of future aviation and IT specialists based on practical mathematical training with the use of information technologies. Their research confirmed a close link between a strong technical foundation and the IT competence of students. In addition, T. Kovaliuk *et al.* (2020) applied an ontological approach to the development and accreditation of educational programmes for training IT specialists in Ukraine, substantiating the advantages of structured knowledge representation for improving the quality of education.

O. Kopishynska *et al.* (2020) substantiated professionally oriented training of specialists through the implementation of cloud information systems, emphasising the need for close cooperation between higher education institutions and IT companies. The authors demonstrated that this format of education makes it possible to align the content of academic training with current labour market requirements, while simultaneously developing students' practical skills that enhance their competitiveness. Particular attention was paid to the introduction of modern cloud technologies into the educational process as a means of developing digital competencies. F. Fraile *et al.* (2023) developed a comprehensive methodological framework for creating personalised learning programmes aimed at upskilling the workforce within the context of the Industry 5.0 concept. In particular, Industry 5.0 focuses on integrating humans into processes of automation and robotisation, with an emphasis on collaboration between people and technologies in order to achieve sustainable development and the personalisation of production processes. In their study, the authors highlighted the importance of taking into account individual needs and levels of prior training, which makes it possible to achieve greater effectiveness in learning and in the development of relevant IT competencies. The proposed model considers adaptability, flexibility and digital transformation as key factors of contemporary education for specialists working in a dynamic, technology-oriented environment.

Despite these significant findings, existing research does not sufficiently address the integration of emotional intelligence, social interaction and interdisciplinarity in the training of IT specialists. In addition, the long-term impact of the proposed models on graduates' adaptation to dynamic changes in the digital labour market has been analysed only to a limited extent. Moreover, despite the aforementioned studies, there remains insufficient investigation into how the integration of sustainable development principles influences the content and structure of educational programmes for IT specialities. Furthermore, the pedagogical conditions under which digital learning technologies effectively contribute to the development of professional competence with due regard to environmental and social responsibility remain underexplored. The aim of the study was to identify contemporary educational technologies that contribute to the development of the professional competence of future IT specialists in the context of sustainable development. The objectives of the study were to analyse digital platforms and tools used in the training of future IT specialists; to determine the impact of educational technologies on the development of professional competence in the context of sustainable development among future IT specialists; and to formulate recommendations for the development of professional competence of future IT specialists in the context of sustainable development.

MATERIALS AND METHODS

The study involved 312 students and 28 lecturers from five higher education institutions that offered training for specialists in the Bachelor's Programme in Computer

Science (n.d.) and the Bachelor's Programme in Software Engineering (2020). The inclusion criteria for students were: studying in the 3rd or 4th year of a bachelor's degree or in a master's degree programme, active participation in educational projects, and use of modern IT platforms in learning. The inclusion criteria for lecturers were teaching core IT-related disciplines, experience in implementing digital educational technologies, and participation in the implementation of sustainable development programmes. First-year students, as well as those who had no experience with project-based learning or did not use the specified digital tools in the educational process, were excluded from the sample. Lecturers whose activities were limited exclusively to theoretical courses without the application of innovative technologies were also excluded. The study was empirical in nature with elements of applied analysis and was conducted between 2021 and 2024. The main objective was to examine the effectiveness of modern educational technologies in developing the professional competence of future IT specialists in the context of sustainable developmentt.

Data were collected using the Google Forms (2024) in an online format through a questionnaire administered to students of the "Computer Science" and "Software Engineering" specialities at five leading technical universities: the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kharkiv National University of Radio Electronics, Lviv Polytechnic National University, Oles Honchar Dnipro National University, and Odesa Polytechnic National University. These higher education institutions were selected due to their high level of academic training in the field of information technology, the availability of modern digital infrastructure, active participation in international projects and sustainable development initiatives, and the implementation of innovative teaching approaches. In addition, an analysis of digital platforms and tools was conducted, including programming languages (Python, Java, C++), the React library, frameworks (Angular, Django), and tools such as Jenkins and Kubernetes, which were used in teaching courses in programming, information security, databases, web development and DevOps. The study also drew on the results of students' project activities, which involved the creation of IT products that took into account the principles of sustainable development, such as energy efficiency, environmental safety, social orientation, inclusivity and the responsible use of digital resources. The questionnaire was aimed at assessing the use of educational technologies and the development of professional competence in the context of sustainable development (Table 1).

Table 1. The study's questionnaire

No.	Question	Answer
1	Educational institution	a) National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"; b) Kharkiv National University of Radio Electronics; c) Lviv Polytechnic National University; d) Oles Honchar Dnipro National University; e) Odesa Polytechnic National University
2	Year of study	a) 3rd year of Bachelor's degree; b) 4th year of Bachelor's degree; c) 1st year of Master's degree; d) 2nd year of Master's degree
3	Which platforms did you use during your studies? (may select more than one)	a) Moodle; b) Google Classroom; c) Microsoft Teams; d) Coursera/edX; e) GitHub; f) Docker; g) AWS Educate; h) Cisco Networking Academy; i) Other
4	How effectively did these platforms contribute to the acquisition of professional skills?	a) Very effective; b) Rather effective; c) Neutral; d) Rather ineffective; e) Completely ineffective
5	Did you participate in projects related to the principles of sustainable development (energy efficiency, inclusivity, digital ethics, etc.)?	a) Yes; b) No
6	How often were practical tasks with real-life cases used during your studies?	a) Constantly; b) Often; c) Sometimes; d) Rarely; e) Never

Table 1. Continued

No.	Question	Answer
7	Assess your level of preparedness for working in an IT speciality after completing the training courses (on a scale from 1 to 5)	a) 1 – Very low; b) 2 – Low; c) 3 – Average; d) 4 – High; e) 5 – Very high
8	Which digital tools do you think have contributed most to your professional development? (open-ended question)	

Source: compiled by the author

Descriptive statistics were used for the analysis to examine the frequency of use of technologies such as GitHub, Docker, Jira, Moodle, Google Classroom, Microsoft Teams, as well as AWS Educate and Cisco Networking Academy virtual labs. A comparative analysis of the effectiveness of these tools in the learning process was carried out by evaluating the results of student projects and participants' self-reports on the level of professional skills acquisition. In addition, an expert survey was conducted among lecturers who actively implemented modern teaching technologies, including simulation environments, Coursera and edX online certification courses, gamification through Codewars, and the integration of CI/CD environments for DevOps practice. This made it possible to determine which technologies contributed to the formation of key professional competencies, such as working with cloud services, process automation, team development, and adapting projects to environmental and social challenges. The questionnaire included the following questions:

1. What specific digital technologies have you implemented in your educational practice over the past two years?
2. How do you assess the effectiveness of using simulation environments in training IT specialists?
3. Have your students taken online certification courses (e.g., Cisco, AWS, Coursera)? What were the results?
4. What advantages and limitations did you observe when implementing these tools in the learning process?
5. How has the use of digital platforms influenced the development of critical thinking, teamwork, and project activities among students?
6. Were the principles of sustainable development taken into account when developing or selecting educational projects and technologies? If so, how exactly?
7. What changes do you consider necessary for the further improvement of the digital training of future IT specialists?
8. How do you assess the level of digital competence of your colleagues and students in the context of the new challenges of higher education?

In addition, contemporary educational approaches were characterised, in particular the use of gamification, the updating of educational programmes to take into account the challenges of digitalisation, the introduction of virtual internships, and the role of organisational culture in shaping the professional identity of future IT specialists. The research was conducted in accordance with the provisions of the American Sociological Association's (1997). Ethical standards and principles of confidentiality were observed.

RESULTS

Analysis of digital platforms and tools in the training of future IT specialists

In the field of F "Information Technology" and F1-F7, the main aspects of popular technologies and platforms such as Python, Java, C++, and web development frameworks, including React, Angular, and Django, were studied. Python was studied as a universal programming tool, particularly in the fields of data analysis, machine learning, and web application development, due to its simplicity and numerous libraries that simplify software development. However, while studying Python, it was noted that one of its limitations is its slower execution speed compared to other languages such as C++. Java was studied as a language for creating scalable enterprise solutions, particularly in the financial and banking sectors, but its complexity for beginners was also noted as one of its drawbacks. The study of C++ covered its use for developing high-performance applications where execution speed is a critical factor. In addition, programming with React, Angular, and Django frameworks was included for developing modern web applications, with an emphasis on their effectiveness in creating interactive and dynamic user interfaces. Other important tools are DevOps platforms, including Jenkins, Docker, and Kubernetes. Using these tools allows for the automation of software deployment processes, which is important for modern development methods such as Continuous Integration (CI) and Continuous Delivery (CD). One of the main advantages is the simplification of environment management and improved development efficiency. However, significant technical training is required to use these tools effectively. Technologies for ensuring information security, such as encryption, firewalls, authentication systems, and security protocols such as HTTPS and SSL, are also widely used in educational programmes. These technologies are necessary to ensure data protection and combat cyber threats. However, their implementation requires a deep understanding of security theory and technical expertise, which can be challenging for students without relevant experience.

In particular, digital technologies such as Moodle allow for convenient course organisation, assignment delivery, and student performance monitoring. Teams and Google Classroom are used for interactive communication

between students and lecturers, organising video conferences and collaborating on projects. During project activities, students create IT products, taking into account the principles of sustainable development, such as energy efficiency, environmental safety and social orientation. For example, students develop web applications using green technology principles that reduce energy consumption, or create inclusive solutions accessible to people with disabilities. This prepares future IT professionals for real-world market conditions and promotes the implementation of sustainable development principles in the IT industry. Despite the many positive aspects, there are also drawbacks, in particular the need to update teaching materials and incorporate the latest tools. Lecturers and students often face difficulties in adapting to rapid changes in technology, which requires constant updating of curricula and resources. Thus, it is important to continue integrating the latest international practices and to provide universities with the necessary infrastructural and technical resources for the implementation of innovative teaching methods.

The impact of educational technologies on the formation of professional competence of future IT specialists in the context of sustainable development

The study revealed differences in the level of use of digital educational technologies among students of technical specialities. Analysis of the responses received made it possible to identify the main digital platforms and tools most frequently used during the learning process, as well as to assess their impact on the development of students' professional competence. A significant proportion of participants noted the effectiveness of digital platforms in mastering the course material and confirmed their participation in project activities that integrate the principles of sustainable development. Table 2 presents the summarised quantitative results of the survey.

Table 2. Results of the assessment of the use of digital technologies and the formation of professional competence in the context of sustainable development

Question	Answer options	Number of people
Educational institution	National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"	75
	Kharkiv National University of Radio Electronics	64
	Lviv Polytechnic National University	61
	Oles Honchar Dnipro National University	58
	Odesa Polytechnic National University	54
Year of study	3rd year of Bachelor's degree	118
	4th year of Bachelor's degree	95
	1st year of Master's degree	62
	2nd year of Master's degree	37
Which platforms did you use during your studies? (may select more than one)	Moodle	245
	Google Classroom	212
	Microsoft Teams	185
	Coursera / edX	167
	GitHub	203
	Docker	129
	AWS Educate	91
	Cisco Networking Academy	114
	Other	48
How effectively did these platforms contribute to the acquisition of professional skills?	Very effective	89
	Rather effective	142
	Neutral	48
	Rather ineffective	23
	Completely ineffective	10
Did you participate in projects related to the principles of sustainable development?	Yes	176
	No	136
How often were practical tasks with real-life cases used during your studies?	Constantly	72
	Often	125
	Sometimes	74
	Rarely	32
	Never	9
Assess your level of preparedness for working in an IT speciality after completing the training courses (on a scale from 1 to 5)	1 – Very low	5
	2 – Low	17
	3 – Average	83
	4 – High	128
	5 – Very high	79

Source: compiled by the author

The data obtained from the survey indicates the widespread implementation of digital educational platforms in the training process for students. Respondents most often cited the use of the Moodle platform (78.5%), which is explained by its versatility, integration into university courses, the ability to organise feedback and effective knowledge control. A significant percentage of students also noted Google Classroom (67.9%) as a convenient tool for communication, access to learning materials, and assessment. This indicates a combination of formal and cloud-based learning environments. Equally important was the widespread use of GitHub (65%), which indicates an emphasis in training programmes on teamwork, version control, and a portfolio approach to project activities. Microsoft Teams, chosen by 59.3% of respondents, indicates the active implementation of integrated solutions for distance and hybrid learning, particularly in the context of pandemic restrictions. It is important to note that more than half of the students (53.5%) used Coursera or edX, demonstrating an interest in acquiring additional knowledge outside of university programmes and a willingness to engage in self-education in a globalised educational environment. Participation in massive open online courses is an indicator of students' desire to expand their competence and focus on interdisciplinarity. Specialised platforms and environments focused on engineering and professional practices constitute a separate category: Docker (41.3%) indicates familiarity with containerisation as part of the DevOps approach, while Cisco Networking Academy (36.5%) indicates that some students are focused on studying computer networks, information security, and certification programmes. The AWS Educate** platform, used by 29.2% of respondents, demonstrates the integration of cloud services into the learning process, which is in line with current trends in IT specialist training. An assessment of the effectiveness of these digital platforms showed that 74% of students consider them to be at least effective in acquiring professional skills (28.5% – "very effective", 45.5% – "rather effective"). Only 8% of respondents consider these tools ineffective (6.7% – "rather ineffective" and 1.3% – "completely ineffective"), which may indicate either shortcomings in the implementation of individual tools or an uneven level of digital literacy among students. At the same time, 17.9% of respondents took a neutral position, indicating the need for further analysis of the factors that influence subjective assessment of effectiveness.

An analysis of participation in projects related to the principles of sustainable development showed that 56.4% of students had such experience. This indicates the gradual introduction of value-oriented approaches in the professional training of IT specialists, in particular an emphasis on social responsibility, ethical use of digital resources, energy efficiency, inclusiveness and cybersecurity. Such integration of sustainable development principles into the educational process contributes to the formation of a holistic professional worldview among students who are capable of responding to the challenges of modern society. Regarding the use of practical tasks with real-life cases, over 63% of respondents indicated that such tasks are used constantly (25.6%) or frequently (37.5%). This is evidence of the widespread implementation of project-based learning as a means of acquiring competencies closely related to the conditions of real production practice. Only 13.5% of participants reported rare or no use of real-life cases, indicating a certain unevenness in the practical component in different curricula or disciplines. The final part of the closed-ended questions in the questionnaire involved self-assessment of the level of readiness to work in the profession. Here, a high level of subjective confidence in one's own knowledge and skills can be observed: 66.3% of respondents rated their readiness as "high" (41%) and "very high" (25.3%). Another 24.7% indicated an average level, which may indicate a need for further professional support or additional practical experience. Only 9% of students rated their level of preparation as low or very low, which indicates the overall positive impact of educational programmes on the formation of readiness for professional activity in the IT sphere.

Analysis of responses to the open-ended question "Which digital tools do you think have contributed most to your professional development?" revealed a wide range of digital tools that respondents believed had contributed most to their professional development. The most frequently mentioned tools were GitHub, Visual Studio Code, Figma, Docker, Jupyter Notebook, as well as cloud platforms such as AWS, Google Cloud Platform, and Firebase. Some students highlighted Notion and Trello as effective tools for planning, organising teamwork, and project management. A significant number of responses contained references to online courses and self-learning environments, including Coursera, edX, and Udemy, indicating the important role of informal learning in the formation of key digital competencies. This also confirms the trend towards the individualisation of educational trajectories and a high level of self-organisation among students. Respondents' answers also mentioned specialised tools such as Postman (API testing), Kubernetes (container orchestration), TensorFlow and PyTorch (artificial intelligence and machine learning), which indicates the depth of student engagement in modern IT development fields. Several students noted the importance of integrated development environments such as IntelliJ IDEA, PyCharm, Eclipse, as well as the use of GitLab CI/CD for automating application deployment and version control, which was particularly valued in project or course programming.

The survey results show a high level of use of digital platforms in the learning process, which correlates with an increase in the effectiveness of professional knowledge acquisition. Analysis of open-ended responses showed that students use a wide range of digital tools not only as part of the learning process, but also for self-education and practical professional growth. Most of them prefer tools that allow them to implement the full cycle of project activities: from development, testing and documentation to

automation, teamwork and presentation of results. This indicates a high level of student motivation to master the digital environment and a desire for adaptive professional development. The results of a comparative analysis of the effectiveness of digital tools in the learning process showed that the use of GitHub, Docker, Cisco Packet Tracer, and AWS has a positive impact on the level of acquisition of practical skills related to software development, containerisation, infrastructure management, cloud services, and network configurations (Table 3).

Table 3. Comparative characteristics of digital tools in the training of future IT specialists

Digital tool	Main purpose	Level of use by students	Effectiveness assessment (based on project results and self-reports)	Characteristics
Moodle	Learning Management System (LMS)	High	Moderate effectiveness in theoretical training	Convenient for organising the learning process, but limited in terms of developing practical skills
Google Classroom	LMS for lecturer-student interaction	High	Moderate effectiveness	Facilitates communication and access to materials, but is not focused on practical IT tasks
Microsoft Teams	Platform for collaboration and video conferencing	High	Average effectiveness	Useful for team interaction, but limited in terms of professional training
GitHub	Service for developing, storing, and sharing code	High	High effectiveness	Develops skills in team development, version control, and collaborative work on program code
Docker	Platform for deploying containerised applications	Average	High effectiveness	Promotes practical understanding of DevOps principles, software deployment and testing
AWS Educate	Virtual environment for learning cloud technologies	Low	High effectiveness in narrow specialisation	Develops practical skills in working with cloud infrastructures, but requires technical training
Cisco Networking Academy	Educational platform for studying computer networks	Average	High effectiveness	Provides in-depth knowledge of network technologies, actively used for certification
Jira	Project management tool	Low	Average effectiveness	Useful for learning Agile methodologies, but requires coordination of teamwork

Source: compiled by the author

Students who used these environments in their project work demonstrated high performance in terms of practical training, independence, technical literacy, and the ability to solve applied problems. These results are also confirmed by the content of self-reports, in which respondents noted that working with these platforms contributed to a deeper understanding of technological processes close to the real production environment, increased confidence in their professional competencies, and increased motivation to learn. At the same time, traditional educational platforms, such as Moodle, Google Classroom, and Microsoft Teams, played an important role in organising the learning process, ensuring communication between lecturers and students, and providing access to learning materials and assignments. However, their impact on the development of practical skills could be limited, so students used other tools as well. Although traditional platforms provide the organisational component of the educational process, the use of specialised simulation and production-oriented digital environments is necessary for the formation of deep professional competencies. The collected data helped to analyse current trends and identify opportunities for further improvement of the learning process (Table 4).

Table 4. Summary of interviews with lecturers on the use of digital technologies in training IT specialists

Question	Key responses	Number of mentions
What specific digital technologies have you implemented in your educational practice over the past two years? (may select multiple options)	Moodle	20
	Microsoft Teams	18
	GitHub, Docker	22
	Cisco Packet Tracer	11
	AWS	14
	Miro	9
	Zoom	5

Table 4. Continued

Question	Key responses	Number of mentions
How would you assess the effectiveness of simulation environments in training IT specialists?	High effectiveness in developing practical skills, particularly in networking, security and DevOps; limitations include students' level of technical preparation and unstable access to resources.	"High effectiveness" – 19
		"Limited effectiveness" – 7
		"Has limitations" – 2
Have your students taken online certification courses (e.g., Cisco, AWS, Coursera)? What were the results?	Yes, they are actively used (Cisco, Coursera, AWS, Google); this has led to improved skills, increased motivation and enhanced competitiveness.	Cisco – 18
		Coursera – 20
		AWS – 10
		Google – 6
What advantages and limitations did you observe when implementing these tools in the learning process?	Advantages: flexibility, interactivity, access to global content; limitations: unstable internet connection, workload, digital inequality.	Advantages mentioned – 28
		Limitations – 24
How has the use of digital platforms influenced the development of critical thinking, teamwork, and project activities among students?	The development of project-based thinking, critical analysis and collaboration was noted through the use of team platforms and joint work on case studies.	Critical thinking – 21
		Teamwork – 23
		Project-based activity – 25
Were the principles of sustainable development taken into account when developing or selecting educational projects and technologies? If so, how exactly?	Yes, within project topics (environmental IT solutions, inclusive interfaces, ethical programming); individual cases were integrated into training courses.	Yes – 17
		Partially – 6
		No – 5
What changes do you consider necessary for the further improvement of digital training for future IT specialists?	The need to improve lecturers' digital competence, develop IT infrastructure, integrate certification programmes, and prepare open simulation-based case studies.	Improvement of digital skills – 22
		Infrastructure – 18
		Certifications – 12
How do you assess the level of digital competence of your colleagues and students in the context of the new challenges facing higher education?	Students: a high but fragmented level, requiring better structuring of knowledge. Colleagues: varying levels, with a need for professional development.	Students – "adequate" – 20
		Colleagues – "mixed levels" – 24

Source: compiled by the author

The analysis of interviews revealed that lecturers actively implement various digital tools, including both traditional learning management platforms and specialised environments that simulate professional situations. This demonstrates a desire to integrate the learning process with practice that is close to the real IT environment. Lecturers consider the use of simulation environments to be an effective approach that allows students to develop not only technical but also analytical skills. These tools contribute to the formation of competencies that are relevant for solving applied problems in the field of IT. At the same time, some difficulties have been identified related to individual barriers for students in working with simulation tools. A significant proportion of lecturers note that online certification courses have become an important addition to educational programmes, providing students with access to the latest knowledge and increasing their competitiveness. This has also created additional opportunities for forming interdisciplinary connections and independent mastery of the material.

Analysis of the responses showed that digital platforms generally have a positive impact on the development of critical thinking skills, teamwork, and the implementation of educational projects. At the same time, attention is drawn to existing limitations: uneven access to digital resources, platform overload, and the need for methodological support. The issue of integrating sustainable development principles is considered through the prism of the content of educational projects: from environmental awareness to ethical use of data. Lecturers noted that sustainable development topics are increasingly finding their way into technical education and require a rethinking of teaching methods. When assessing the digital competence of students and colleagues, most respondents noted positive dynamics, although they drew attention to the need for systematic development of digital skills at all levels. Among the strategic changes required by the system are infrastructure improvements, lecturers training, and the integration of digital resources into curricula, taking into account global challenges.

Recommendations for developing the professional competence of future IT specialists in the context of sustainable development

Based on the analysis of educational practice and current trends in the field of information technology, a set of recommendations for developing the professional competence

of future IT specialists in the context of sustainable development has been identified. In particular, modern IT companies such as Microsoft, Google, IBM, Accenture and SAP place requirements on graduates that go beyond deep technical knowledge, including proficiency in programming languages, databases, cloud technologies and infrastructure management, and also emphasise the importance of critical thinking, teamwork and lifelong learning. They additionally expect candidates to demonstrate ethical responsibility, problem-solving abilities and an understanding of the environmental implications of technological activity. Requirements for professional training highlight, in particular, the need for knowledge in the areas of software development, infrastructure, IT service management and security assurance. The IEEE standard defines a body of knowledge and practices for software developers, covering the stages of development, testing, maintenance and improvement of products, which help to achieve high software quality. The ITIL standard defines methods of IT service management aimed at improving the efficiency and quality of services provided to users, including the implementation of best practices in incident, problem and change management, as well as service continuity management.

It is recommended to integrate the use of modern educational platforms into the training of IT specialists, such as Cisco Networking Academy, Microsoft Learn, IBM SkillsBuild and Google Cloud Skills Boost, which offer applied courses with an emphasis on the safe and ethical use of IT solutions. Particular attention should be paid to mastering tools for developing energy-efficient code, designing socially oriented applications, and understanding the principles of "green" IT infrastructure. Innovative approaches include incorporating simulations of sustainable projects into curricula, analysing the software life cycle, developing environmentally sensitive IT products, and using big data and artificial intelligence to address sustainable development challenges. All of these measures contribute to developing students' systemic understanding of the role of IT in a sustainable future and ensure that specialist training meets the needs of the modern labour market. For Ukrainian universities seeking to enhance the training of future IT specialists in the context of sustainable development, it is important to take into account global educational trends and innovations. One of the key recommendations is the active adoption of international experience in the use of advanced educational technologies, such as artificial intelligence (AI) and gamification. Artificial intelligence, particularly in the context of personalised learning, can be implemented to create adaptive learning platforms that take into account individual students' needs, levels of knowledge and learning styles. Examples include platforms such as Coursera and edX, which use AI algorithms to recommend courses and analyse learner performance, adapting educational content accordingly.

Another recommendation is the integration of gamification elements into educational programmes in order to increase student motivation and engagement. An example of this approach is the use of platforms such as CodeCombat, which apply gamification to the learning of programming languages and foreign languages. Modern teaching methods that incorporate elements of gamification provide students with opportunities to master courses in an interactive and engaging format, where they can earn points, progress to higher levels and receive real-time feedback. For example, when learning programming, a student completes a series of practical tasks and receives virtual rewards for successful completion, which increases learning motivation. At the same time, the training of future specialists in the field of information technology requires updating the content of educational programmes by introducing new modules devoted to relevant topics such as cybersecurity, the ethics of artificial intelligence and big data analytics. This is particularly important in the context of rapid technological development and the growing need to ensure data security. For instance, a course on AI ethics may include the analysis of cases of algorithmic discrimination and discussions of the principles of transparency and accountability in the development of automated solutions. Such educational components help students not only to acquire technical knowledge but also to develop an understanding of the ethical, legal and social aspects of working with modern digital technologies.

In addition, the introduction of virtual internships as a form of professional training is becoming an important innovation in the educational process, allowing students to gain practical experience without leaving their educational institution or home. For example, a student specialising in "information systems" may participate in a virtual internship at an international software development company, performing real tasks through a specialised platform that ensures communication with mentors and monitoring of task completion. Such internships make it possible to become familiar with the specifics of work in various IT fields, business and science, and to develop skills that are critical for a modern specialist, including self-organisation, critical thinking and effective teamwork. At the same time, a flexible schedule and the absence of the need for physical presence allow students to combine study with other activities. Moreover, virtual internships create opportunities for participation in international projects, thereby broadening students' professional horizons.

An important component of effective training for IT specialists is also consideration of the role of organisational culture in shaping their professional identity. Organisational culture – the set of values, norms, traditions and styles of interaction within a collective – contributes to awareness of one's professional role, the formation of ethical principles and the development of the ability to work effectively in a team. For example, when participating in a joint project within a company that supports openness and mutual assistance, a student learns not only to perform technical tasks but also to value shared responsibility, respect for colleagues and the importance of feedback. Through engagement in real tasks, the use of corporate

standards, participation in training sessions and joint initiatives, young specialists are gradually integrated into the professional environment, which influences their readiness to make decisions, implement innovations and adapt to change. In this way, organisational culture becomes an integral factor in shaping a well-rounded professional who is capable not only of working with technologies but also of acting responsibly within social and professional contexts. To integrate these innovative approaches, universities can cooperate with international educational platforms, involve foreign experts in curriculum development, and adapt advanced teaching methodologies to the Ukrainian context. Drawing on international experience will enable Ukrainian universities not only to improve the quality of education but also to make the training of IT specialists more closely aligned with the requirements of the modern labour market, which in turn will contribute to the country's sustainable development and the integration of its economy into the global space.

DISCUSSION

The results of this study showed that the use of digital technologies, in particular cloud platforms, interactive learning management systems, and massive open online courses, can contribute to the development of professional competence of future IT specialists. This approach ensures the accessibility of knowledge, flexibility in learning, and adaptability to the individual educational needs of students. These conclusions are consistent with the results of the study by O. Popelo *et al.* (2024), who pointed to a global trend towards the digitalisation of universities in the context of sustainable development, where information technology is a key tool for the modernisation of education. This study found that IT students demonstrate high motivation to learn in a digital environment, especially when project-based learning elements are present. This correlates with the conclusions of M. Ramírez-Montoya *et al.* (2021) and H. Tin as (2022), who determined that future educational programmes should focus on the development of self-organisation, interdisciplinarity and emotional intelligence skills, which can be achieved through the integration of innovative technologies. It is important to note that the effective use of educational technologies also promotes inclusiveness and consideration of different learning styles. The results of this study confirmed that students successfully assimilate material through multimedia content, simulations and visualisations. The same conclusions are reflected in the study by S. Rodríguez-Cano *et al.* (2022), which states that learning support technologies have a positive impact on the ability of students with specific learning difficulties to achieve professional competence. This is partly consistent with the findings of S. Hyrynsalmi (2024), who emphasised the need to create favourable conditions for women returning to the IT sector, as this can significantly enrich the professional environment and increase innovation in the industry. This approach also fits in well with the concept proposed by M. Mawardi *et al.* (2024) and Y. Meng *et al.* (2024), who studied the impact of digital technologies on the development of higher education. The researchers found that digital technologies improve the accessibility of education, increase the interactivity of learning, and contribute to the personalisation of the learning process for students.

An analysis of the effectiveness of massive open online courses in programming education showed positive dynamics in the formation of professional skills such as problem solving, teamwork, and independent learning. This is confirmed by the results of a study by S. Sharov *et al.* (2021), which states that MOOCs are a promising form of training for IT specialists due to their flexibility, accessibility, and adaptability to the needs of the labour market. Another result of this study is the identification of the need to update the content of educational programmes to take into account sustainable development and digital transformations. It was found that traditional disciplines should be supplemented with modules on cybersecurity, artificial intelligence ethics, and big data analysis. These results are consistent with the conclusions of H. Shi *et al.* (2024), who pointed to the need to revise information systems curricula towards modern technological and socially responsible areas. In addition, the use of innovative platforms for digital learning ensures an interactive learning process and creates conditions for flexible knowledge acquisition. M. Handrich & M. Otterbach (2024) also showed that the use of digital platforms for learning can significantly improve the effectiveness of knowledge and management in corporate IT systems, which has a positive impact on the training of future specialists, improving their adaptation to changes in the professional environment.

This correlates with the research of U. Stoltenberg and G. Michelsen (2023), who emphasised that sustainable development should be integrated into digital education as an integral part of training globally oriented specialists. In the context of the sustainable development of technologies for training future IT specialists, it is important to create learning environments that promote the development of professional competencies in line with the modern requirements of the digital economy. As demonstrated by the study of O. Korotun *et al.* (2020), models for the use of cloud technologies in teaching databases are effective in the training of IT specialists, as they provide opportunities for learning in an interactive and accessible format. These results were consistent with the findings of P. Fidalgo & J. Thormann (2024), who emphasised the importance of integrating artificial intelligence and distance learning into processes of continuous professional development. They argue that distance learning supported by new technologies makes it possible to ensure sustainable development in the field of IT specialist training, as students are able to acquire new knowledge without temporal or spatial limitations. Particular attention in the present study was paid to virtual internships, which demonstrated high effectiveness in the development of practical skills. This corresponds with the research of A. Tolentino & T. Palaoag (2022) and

Y. Wei (2024), who noted that models for predicting student performance in virtual internships help to improve the quality of training of future IT professionals.

Special attention should also be given to the importance of soft skills in the preparation of IT personnel. These findings correspond with the conclusions of G. Tomer & S. Mishra (2023), who established that career progression and job satisfaction among IT specialists directly depend on the level of development of their soft skills. The study also highlights the role of organisational culture in the formation of the professional identity of future IT specialists. M. Topuzovska Latkovikj *et al.* (2023) also considered the technological preferences of IT specialists in connection with organisational culture and corporate values. With regard to the implementation of flexible project management methodologies, this study showed that the use of innovative approaches in the educational process stimulates student initiative and increases the level of professional responsibility. This aligns with the findings of M. Neumann & L. Baumann (2022), who integrated professional Scrum training into university courses on IT project management and obtained positive results in the development of managerial competences.

An important component of professional competence formation is continuous professional development through participation in practice-oriented courses and training programmes. The present study found that students should have experience of participation in the activities of university computer centres in order to better adapt to the professional environment. This conclusion is consistent with the results of B. Zulauf & N. Knipprath (2020), who demonstrated the effectiveness of practical training in university IT centres as a foundation for the development of professional competence. Another component of the formation of professional competence among future IT specialists is practical training carried out through adherence to IT industry standards. As noted by A. Celestial-Valderama (2023), internship experience in IT companies is an important stage in the professional development of future IT specialists. The conclusions of this study also correspond with the findings of M. Chandrakala *et al.* (2024), who indicated that the effective use of learning and development data through HR analytics enables the creation of more accurate and personalised IT training programmes, thereby increasing the effectiveness of internships.

Particular attention should also be paid to the establishment of specialised research and training centres for the preparation of IT specialists, as proposed by S. Gulyamov *et al.* (2024) and X. Yuan (2024). They emphasised that such centres, which integrate innovative teaching methods and digital technologies, contribute to improving the quality of education and meet the requirements of sustainable development. This approach is also supported by the work of S. Jacobs & S. Jaschke (2023), which focuses on the use of large language models in the training of IT specialists. They noted that these models can be an important tool for developing new professional skills in conditions of constant technological change. Overall, the results of this study confirm the thesis that effective training of future IT specialists in the context of sustainable development is possible only through the combination of advanced digital technologies, practice-oriented approaches and interdisciplinary integration. Thus, the consistency of the obtained results with the above-mentioned studies indicates the soundness of the chosen strategy for the formation of professional competence among future IT specialists.

CONCLUSIONS

The study confirmed that the introduction of modern digital technologies has a positive impact on the professional competence of future IT specialists. Active use of platforms such as GitHub, Moodle, Cisco Networking Academy, and cloud tools contributes to the development of practical skills, critical thinking, and teamwork abilities. A significant proportion of students (76%) recognised these technologies as effective for professional growth. More than 65% of respondents participated in projects related to the principles of sustainable development, which indicates the integration of ethical and environmental components into technical training. Students also noted that online courses on the Coursera and edX platforms provide additional opportunities for in-depth study of the material and obtaining international certificates, which increases their competitiveness in the labour market.

A comparative analysis of digital tools shows that 56.4% of students had experience working with the latest tools. This indicates the gradual introduction of value-oriented approaches to the professional training of IT specialists, in particular an emphasis on social responsibility, ethical use of digital resources, energy efficiency, inclusiveness and cybersecurity. Such integration of sustainable development principles into the educational process contributes to the formation of a holistic professional worldview of students who are able to respond to the challenges of modern society. Regarding the use of practical tasks with real cases, more than 63% of respondents indicated that such tasks are used constantly (25.6%) or often (37.5%). This is evidence of the widespread implementation of project-based learning as a means of acquiring competencies closely related to the conditions of real production practice. Interviews with lecturers confirmed the trend towards the active implementation of digital technologies in the learning process. GitHub and Docker were the most popular, mentioned 22 times, accounting for 28.2% of the total number of responses.

Moodle and Microsoft Teams were used by 20 and 18 lecturers, respectively (25.6% and 23.1%), while other tools, such as Cisco Packet Tracer (11 mentions, 14.1%) and AWS (14 mentions, 17.9%), were less common. Regarding the effectiveness of simulation environments, 70.5% of lecturers indicated high effectiveness in developing practical skills, particularly in networking and security, although 14.1% noted limitations due to unstable access to resources and insufficient technical training of students. The process of

online certification, particularly through Cisco, Coursera, AWS, and Google, was actively used, with most mentions relating to Coursera (25.6%) and Cisco (23.1%). 79.5% of respondents recognised the advantages of digital tools, such as flexibility and access to global content, although 61.5% noted problems with internet connectivity and digital inequality. The study was limited by the small number of participants, which may not fully reflect the experience of all higher education institutions, as well as the predominantly self-reported nature of the responses, which may contain subjective assessments. Prospects for further research include expanding the sample of participants, including students of different educational levels and specialisations, and conducting a comparative analysis between different countries.

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Технології навчання та формування професійної компетентності майбутніх IT-фахівців у контексті сталого розвитку

Анотація. Метою дослідження було вивчення інструментів і технологій, що використовуються у освітніх програмах провідних технічних університетів України для підготовки майбутніх IT-фахівців. Методологія дослідження включала анкетування 312 здобувачів освіти та 28 викладачів, аналіз цифрових платформ і технологій, а також порівняльний аналіз ефективності використаних інструментів для формування професійної компетентності майбутніх IT-фахівців у контексті сталого розвитку. У дослідженні було вивчено вплив сучасних цифрових технологій на формування професійної компетентності майбутніх IT-фахівців. Активне використання таких платформ, як GitHub, Moodle, Cisco Networking Academy та хмарні інструменти, підтвердило позитивний вплив на розвиток практичних навичок і критичного мислення. У дослідження було визначено, що 89 студентів визнали ці технології ефективними для професійного зростання. Більше 176 респондентів брали участь у проєктах, що включають принципи сталого розвитку, що свідчить про інтеграцію екологічних і етичних аспектів у навчальний процес. Також 167 студентів відзначили ефективність онлайн-курсів на платформі Coursera та edX для поглибленого вивчення матеріалу, що підвищує їх конкурентоспроможність. Аналіз результатів показав, що сервіси на кшталт GitHub, Docker, AWS Educate та Cisco Networking Academy відіграють ключову роль у формуванні практичних, проєктно орієнтованих навичок. Натомість інструменти організації навчального процесу – такі як Moodle та Microsoft Teams – мають інше функціональне призначення й використовуються передусім для комунікації, управління навчальними матеріалами та підтримки освітнього середовища, а не для розвитку прикладних технічних компетентностей. Практичне значення роботи полягає у тому, що її можуть використовувати викладачі, освітні установи та розробники навчальних програм для вдосконалення процесу підготовки IT-фахівців, інтегруючи сучасні цифрові інструменти та технології у навчальний процес з урахуванням принципів сталого розвитку

Ключові слова: освітній процес; підготовка фахівців; інноваційні технології; процес програмування; практичні навички