INSTITUTE FOR DIGITALISATION OF EDUCATION OF THE NAES OF UKRAINE

TEACHERS' SELF-ASSESSMENT OF DIGITAL COMPETENCE:

RESULTS OF A NATIONWIDE SURVEY IN WARTIME CONDITIONS

ANALYTICAL MATERIALS

2nd EDITION, REVISED AND EXPANDED, TRANSLATED INTO ENGLISH

- DIGITAL COMPETENCE
- ARTIFICIAL INTELLIGENCE
- VIRTUAL AND AUGMENTED REALITY
- STE(A)M EDUCATION
- PROFESSIONAL DEVELOPMENT

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The preprint presents analytical materials on teachers' self-assessments of digital competence, as well as the results of nationwide teacher surveys conducted in 2023 and 2024, highlighting their attitudes towards the use of digital tools for teaching and learning in wartime conditions. It provides an overview of international frameworks related to digital competence. The publication addresses teachers' competence in the use of information and communication technologies (ICT) and presents an example of teachers' self-assessment of their use of AI, virtual reality, and augmented reality in implementing STE(A)M projects.

The publication describes theoretical approaches and practical experience in organising surveys of teachers. It outlines proposals for the digitalisation of education, the development of teachers' digital competence, and the enhancement of their professional qualifications. Theoretical approaches and practical developments concerning the use of ICT in professional education and teacher professional development are also presented.

The publication is intended for teachers, researchers, education administrators, lecturers, doctoral and postgraduate students, university students, and the wider educational community.

The present study is based on data from the 2024 nationwide survey previously reported by an analytical preprint [40]. The present analytical materials provide a revised and expanded analysis of these data, with a particular focus on teachers' digital competence, technology use, and professional development needs in the wartime conditions.

2nd edition, expanded and translated.

SUMMARY

The preprint presents analytical materials on teachers' self-assessment of digital competence, as well as the results of a nationwide survey of teachers conducted in 2023–2024, which examines their attitudes towards the use of digital tools for teaching.

An overview of international framework documents related to digital competence is provided. The authors' perspective on teachers' competence in the use of artificial intelligence (AI) is presented, together with an example of teachers' self-assessment of the use of AI, virtual reality, and augmented reality in the implementation of STE(A)M projects.

The preprint describes theoretical approaches and practical experience in organising surveys of teachers. Proposals are presented for the digitalisation of education, the development of teachers' digital competence, and the enhancement of their professional level. Theoretical approaches and practical developments concerning the use of ICT in professional education and in teachers' professional development are also described.

For teachers, researchers, education managers, lecturers, doctoral students, postgraduate students, university students, and the wider educational community.

The materials are published in the authors' original version. The authors are responsible for the accuracy of the information provided. The survey results were previously reported in a preprint by Ovcharuk, Soroko, and Shymon (2024) [40].

The Authors' Dataset [41].

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INTRODUCTION

The analytical materials present the technology and tool for the self-assessment of teachers' digital competence, which were piloted in 2023 and 2024. When developing the technology and tool for the self-assessment of teachers' digital competence, the limitations associated with the organisation of the survey that could affect the results obtained were taken into account. A significant proportion of teachers, students, and education professionals are under stress and are forced to adapt to the conditions of their regions, cities, and villages, which are constantly exposed to shelling, power outages, and humanitarian and environmental crises. The psychological consequences of the war, particularly among children, are also significant and will continue to affect them for some time. All these factors also affect teachers, some of whom have lost their jobs and are located in temporarily occupied territories or are temporarily displaced from their places of permanent residence. The forced temporary evacuation and displacement of students and teachers, as well as the loss of school infrastructure, contribute to emotional tension among education seekers and their families. Teachers are forced to adapt to new conditions while simultaneously organising the educational process. Maintaining continuous communication with teachers and schools through online tools, as well as conducting teacher surveys, contributes to overcoming stressful situations. Providing opportunities for teachers to express their views and identify their professional development needs motivates them towards professional growth and helps them overcome difficulties in their work.

In May 2023, the Ministry of Education and Science of Ukraine issued Order No. 563 of 15 May 2023, "On Approval of Methodological Recommendations on Certain Issues of Obtaining Education in General Secondary Education Institutions under Martial Law in Ukraine," which defines options for obtaining education during martial law, procedures for assessing learning outcomes, obtaining education documents, and other relevant matters. The Order states that schools should take into account the additional workload experienced by students and teachers who study and work remotely, including situations in which children simultaneously receive education in countries providing temporary protection.

The emergence of new challenges for teachers and the education system caused by the war, according to educators, is reflected in the fact that 79.3% of respondents work remotely with internally displaced children, while 60.2% of respondents work remotely with Ukrainian refugee children in other countries. At the same time, educators believe that the majority of children who are abroad study simultaneously within two education systems, as indicated by the responses of 72.3% of respondents. This indicates a heavy learning workload for students, which affects their psychological and physical well-being and may result in learning losses in the future. Despite the difficulties faced by teachers working with internally displaced children and refugees, the majority of respondents (89.7%) indicated that sufficient online didactic materials are already available for preparing distance learning sessions under wartime conditions [32]. This indicates that a sufficient body of materials was developed during the COVID-19 pandemic and that teachers have acquired the necessary resources and experience for distance work.

The majority of respondents were represented by such categories as primary school teachers, foreign language teachers, Ukrainian language and literature teachers, mathematics teachers, computer science teachers, and school administrators. In our view, this indicates their greater activity and interest in using ICT for organising distance learning and implementing the New Ukrainian School education reform.

The main subject of the study within the implementation of the self-assessment tool is teachers' digital competence. Digital competence is understood as the conscious and critical use of technologies of the digital society (Information Society Technology, IST) for work, leisure, and communication [2]. In the recommendations of the European Parliament and of the Council, digital competence is defined as the confident, critical, and responsible use of digital technologies for learning, work, participation in society, and interaction with digital technologies. It includes information literacy, communication and collaboration, media literacy, creation of digital content (including programming), safety (including digital well-being and cybersecurity), intellectual property issues, problem-solving, and critical thinking.

To harmonise the developed tool with international approaches, the authors based it on the framework document presented by the European Commission in 2016. European organisations and institutions, including the Joint Research Centre (JRC), launched a strategy for implementing and supporting a range of studies and initiatives entitled "Learning and Skills for the Digital Era." These initiatives were aimed at studying the impact of ICT on learning and teaching, as well as identifying a range of indicators (descriptors) that could serve as benchmarks for monitoring and assessing the digital skills and competences of modern individuals [2].

In 2016, the European Commission introduced the Digital Competence Framework for Citizens (DigComp 2.0: Digital Competence Framework for Citizens). In 2017, it was updated and presented under the title "Digital Competence Framework for Citizens: Eight Proficiency Levels with Examples of Use" (DigComp 2.1: Digital Competence Framework for Citizens) in Brussels, Belgium [4].

In 2022, the Digital Competence Framework for Citizens was updated to incorporate aspects related to the use of artificial intelligence (Digital Competence Framework, DigComp 2.2, 2022) [8]. The framework became a reference point for European education systems in developing standards and curricula for educational institutions at all levels. Of particular importance is its alignment with the strategic provisions of the updated European Key Competences for Lifelong Learning Framework (2018), in which digital competence is defined as both a key and transversal competence.

The study was conducted at the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine within the framework of the research project "Methodology for Monitoring Studies of the Effectiveness of the Information and Digital Environment of General Secondary Education Institutions in the Context of Ukraine's European Integration," State Registration No. 0123U100497.

CHAPTER 1. THEORETICAL AND METHODOLOGICAL APPROACHES TO SELF-ASSESSMENT AS A PEDAGOGICAL CATEGORY

The assessment and self-assessment of educational processes currently carried out by general secondary education institutions are established within the regulatory and legal framework of Ukrainian education legislation [36]. In particular, issues related to the assessment and self-assessment of the quality of education in educational institutions are regulated by the Laws of Ukraine "On Education" (Article 41, Part 3 of Article 48) and "On Complete General Secondary Education" (Article 42) [26], the Procedure for Monitoring the Quality of Education approved by Order No. 54 of the Ministry of Education and Science of Ukraine dated 16 January 2020 [22], registered with the Ministry of Justice of Ukraine on 10 February 2020 under No. 154/34437, and the Methodology for Assessing Educational and Management Processes in General Secondary Education Institutions, as well as by the Order of the Ministry of Education and Science of Ukraine "On Approval of Methodological Recommendations on the Formation of an Internal System for Ensuring the Quality of Education in General Secondary Education Institutions" dated 30 November 2020 No. 1480 [21].

As a rule, a comprehensive study and self-assessment of the quality of educational activities in general secondary education institutions is carried out in the following areas: the school educational environment; the system for assessing students' learning outcomes; pedagogical activity; and management processes [36].

As stated in Order No. 54 of the Ministry of Education and Science of Ukraine concerning the procedure for monitoring the quality of education [22], the objects of monitoring may include:

- depersonalised information about participants in the educational process;
- educational and management processes in educational institution(s);
- various types of activities of participants in the educational process (learning, teaching, organisational, management, etc.);
- conditions for carrying out educational and management activities (material and technical, sanitary and hygienic, regulatory and legal, staffing, financial, educational and methodological, etc.);
- results of the implementation of educational changes and innovations;
- the state of organisation of the educational process in an educational institution;
- learning and development outcomes of education seekers and the development of their competences;
- other objects.

The assessment of teachers' professional qualities as specialists is studied by many researchers. The authors of the manual *Theory and Practice of Assessing Learning Achievements*, O. Shcherbak, N. Sofii, and B. Bovych, consider the quality of a specialist to be an objective set of properties and characteristics (knowledge, abilities, skills, personal qualities, capabilities, communication and other qualities) that define a person as a specialist in a particular profession. The quality of specialist training is a set of its essential properties and characteristics, the level of which is formed in the

course of educational activities and should meet the requirements of consumers (society, the labour market, employers, and the individual) [39].

The authors believe that reforming the education system entails a certain reconsideration of the assessment system. Although the work focuses on the assessment of students' learning achievements, the authors offer new perspectives on the process and concept of assessment, proposing that students' qualities be assessed using Bloom's Taxonomy, as well as formative assessment, the purpose of which is not limited to verifying acquired knowledge and developed abilities and skills, but also includes the achievement of other objectives [39, p. 25].

The authors also explain the concept of self-assessment, which, in their view, occurs when a student independently assesses their own activity.

Bloom's Taxonomy is a taxonomy of educational objectives in the cognitive domain proposed in 1956 by American psychologist Benjamin Bloom. A working group led by B. Bloom developed rules for the unambiguous formulation and ordering of learning objectives. They identified objectives in the cognitive domain, objectives in the affective domain (expressed through perception, interests, inclinations, abilities, etc.), and psychomotor objectives (writing, language, physical, and occupational skills). Cognitive objectives can be defined through such elements of learning as understanding, reproduction, application, analysis, synthesis, and evaluation. Learning objectives in the cognitive domain can be defined through the following elements of learning, also referred to as the elements of Bloom's Taxonomy: knowledge, understanding, application, analysis, synthesis, and evaluation [39, p. 97].

Self-assessment has two important characteristics: first, it is a continuous and ongoing process that accompanies the activity itself; second, it takes into account hidden shortcomings known only to the learner, which often remain outside the scope of external assessment [39, p. 29].

Today, the State Service for Education Quality of Ukraine is responsible for issues related to the assessment and certification of teachers. In particular, information materials prepared for the State Service for Education Quality of Ukraine within the "Education Quality Assurance System" initiative, implemented as part of the "Supporting Government Reforms in Ukraine" (SURGe) project, state that, as part of developing an internal quality assurance system, a school principal can monitor the work of each teacher and, based on such an examination, draw conclusions that can improve the quality and effectiveness of teachers' work.

Among the range of tools for studying pedagogical activity, the State Service for Education Quality of Ukraine proposes observation, questionnaires, interviews, focus groups, examination of documentation, and others. An important area identified by the State Service for Education Quality of Ukraine is teachers' proficiency in working under distance learning conditions. Distance learning requires teachers to adapt their own approaches, educational materials, and working styles, as well as to search for additional online resources and sources of information.

It is important to understand which resources teachers use, whether they diversify their forms of work with students, whether they provide opportunities for students who are unable to connect to an interactive online platform or attend an online lesson to make up missed classes, and whether they adjust their lesson plans accordingly. Thus, teachers' proficiency in using digital tools is an object of assessment/self-assessment of teachers' professional competences.

Today, self-assessment is viewed as a process that leads individuals to assess their own qualities. Self-assessment is an element of self-awareness characterised by emotionally charged evaluations of oneself as a person, one's abilities, ethical qualities, and actions, while at the same time serving as an important regulator of behaviour. Self-assessment determines a person's relationships with their surroundings, their critical attitude, demands placed on themselves, and attitudes towards successes and failures. Thus, self-assessment affects the effectiveness of a person's activities and their personal development [34; 38].

The professional standard "Teacher of a General Secondary Education Institution," approved by Order No. 1225 of the Ministry of Education and Science of Ukraine dated 29 August 2024, states that teachers' professional competences include, in particular, assessment and analytical competence (Appendix 1). This competence is understood as the ability to assess the learning outcomes of education seekers; the ability to analyse their learning outcomes; and the ability to develop education seekers' capacity for self-assessment and peer assessment of learning outcomes [30].

The objects and means contributing to the implementation of this professional competence of teachers include a personal computer (laptop) and other office equipment; educational programmes, model curricula, curricula, textbooks, manuals, recommendations, visual aids, pedagogical software, electronic digital platforms, electronic (digital) educational resources, etc. [30].

The new standard describes information and digital competence (Appendix 4). According to the document, the information and digital competence of a teacher in a general secondary education institution includes the following knowledge, abilities, and skills:

Knowledge:

- digital technologies in the field of education;
- methods and techniques for using digital technologies in the educational process;
- rules for safe work with digital devices and in the online environment.

Abilities:

- to apply digital technologies to search for, create, process, and disseminate educational content;
- to use digital technologies to organise and conduct the educational process;
- to create and use electronic educational resources;
- to protect information.

Skills:

- critical thinking for evaluating information and using digital technologies;
- communication and collaboration using digital technologies;
- safe and ethical work with digital technologies.

Thus, this competence encompasses knowledge of digital technologies, the ability to apply them in the educational process, and skills related to critical thinking, communication, and safe work with them.

Self-assessment is a psychological and personal construct that enables an individual to assess their physical and mental state, abilities, orientation, activity, social significance, relationships with the external world, other people, and social groups. Self-assessment is an essential condition for the implementation of self-control and self-improvement as important forms of self-directed behaviour.

If self-assessment is understood as a personal construct, then self-assessment as a process is directed towards an individual's evaluation of their own qualities and state.

In our context, we consider teachers' self-assessment in relation to their use of ICT for professional purposes. This process leads teachers to assess their readiness and ability to operate digital tools, means, and resources in the course of their professional pedagogical activities and for their own needs under contemporary conditions.

Since self-assessment is a personal construct, the authors of the survey did not aim to identify respondents' own self-assessment. Rather, they sought to reproduce the process of self-assessment that enables an individual to determine their own level of digital competence and identify problems and gaps that need to be addressed for further professional and personal improvement.

Thus, teachers' self-assessment is a process in which educators independently analyse and assess their own professional activities, achievements, strengths, and weaknesses. This enables them to better understand their abilities, identify areas for improvement, and pursue professional development.

Teachers' self-assessment includes:

1. **Reflection on their own teaching practice** — analysis of teaching methods, interaction with students, and achieved outcomes.
2. **Assessment of their own level of knowledge and professional competences** in the subject area and pedagogy in general.
3. **Identification of strengths and opportunities for improvement** — for example, classroom management, the use of innovative teaching methods, etc.
4. **Setting professional development goals** — identifying which skills or knowledge need to be improved.
5. **Developing a self-development plan** — courses, training, observation of colleagues, etc.

In the learning process, contemporary researchers identify the so-called assessment and reflective component as a constituent of teachers' professional competence [35]. Regular analysis of teaching proficiency helps teachers identify their strengths and opportunities for further development and improvement. Self-assessment also helps teachers take a critical view of their work, identify growth potential, and improve the effectiveness of the educational process.

Today, many methods enable teachers to conduct self-assessment and analyse their own teaching practice. These methods include keeping a diary or observation journal, in which teachers regularly record information about lessons, students' reactions, exchanges of views with colleagues, and analyses of the methods and materials used. This makes it possible to analyse what worked and what requires changes in teaching practice.

Another method of self-assessment is reviewing and analysing video recordings of lessons and conducting self-analysis. Reviewing recorded lessons helps teachers observe their work from an external perspective, including their gestures, speech, and interaction with the class.

Feedback from students is also important. Such feedback may be obtained through questionnaires or informal surveys of students, primarily those in upper grades, concerning teachers' strengths and weaknesses, as well as through collecting their suggestions.

Peer observation is also a method of self-assessment, since attending lessons conducted by more experienced teachers to exchange experience and ideas can contribute both to collective reflection and to teachers' reconsideration of their own approaches to improving teaching methods and personal development.

In addition, teachers can conduct self-analysis through the lens of professional standards or competences for teachers and compare their activities with quality criteria and indicators defined in state regulatory documents.

It is also important for teachers to continuously analyse students' educational outcomes. Assessing the level of material acquisition on the basis of tests, assignments, and projects completed by students provides an understanding of teaching effectiveness.

Teachers may also conduct structured self-assessment using questions prepared in advance and in accordance with general categories of professional responsibilities, such as lesson planning, use of resources, student assessment, etc.

Online Tools for Self-Assessment

Today, many online tools can assist teachers in conducting self-assessment. These include:

- **Google Forms, SurveyMonkey, and Typeform** — platforms for creating surveys. Teachers can create self-assessment questionnaires and surveys for students.
- **GoObserver** — a web application for self-observation of one's own lessons through video recording and analysis according to specified categories.
- **TeacherEvaluationSoftware** — an online system that allows teachers to upload evidence of their professional activities and receive feedback from administration.
- **BookWidgets** — a tool for creating interactive self-assessment worksheets and webquests based on learning objectives.
- **TeacherPortfolios** — a cloud-based service for creating an electronic teacher portfolio containing examples of work, videos, lesson plans, etc.
- **Bloomboard** and **Participate** — professional development tracking tools that help users set goals and monitor progress.
- **EdPuzzle** — a tool that allows questions to be embedded in educational videos and students' responses to be analysed.
- **Educate – Online Classroom App** — a web application that helps teachers create schedules, plan lessons, create and organise educational materials, and perform other tasks.

The use of such digital tools can facilitate the collection, structuring, and analysis of information for the self-assessment of teaching practice. In addition, teachers can use these tools to survey students and colleagues and, based on the results obtained, identify ways to improve the teaching process.

For example, **Educate – Online Classroom App** is a web application specifically developed to organise teachers' teaching practice. It helps teachers create and plan lessons, develop and conduct assessments, and distribute educational materials.

To conduct their own self-assessment, teachers need to be able to use online tools that support the assessment and self-assessment of students. Free online tools that teachers can use for students' self-assessment include:

- **Google Forms** — a free Google tool for creating surveys and questionnaires. Teachers can create forms for self-assessment, survey students, and collect feedback.
- **Microsoft Forms** — a similar free tool from Microsoft Office 365 for creating online forms and surveys.
- **Socrative** — a platform that helps create interactive exercises, tests, and surveys to engage students during lessons. Teachers can analyse responses and performance.
- **Seesaw** — an application for creating digital portfolios in which teachers can collect samples of students' work, plan lessons, and receive feedback.
- **Rubistar** and **iRubric** — websites for creating rubrics. Teachers can create their own rubrics for self-assessment of the achievement of learning objectives.
- **Blogs and wikis** — platforms such as WordPress.com and PBWorks allow users to maintain online journals with reflections and publish examples of best practices for feedback.
- **YouTube and Vimeo** — free video-hosting services that can be used to record lessons and conduct video-based self-analysis.

It should be noted that most free tools have limited functionality; however, they can still be useful for self-assessment.

CHAPTER 2. SPECIFIC FEATURES OF TEACHERS' USE OF STE(A)M-ORIENTED TOOLS: CHARACTERISTICS OF DIGITAL SKILLS

In the development of dynamic education, the integration of science, technology, engineering, arts, and mathematics (STEAM) has emerged as a transformative approach that promotes interdisciplinary learning and prepares students for the challenges of a rapidly changing society. The effective implementation of STE(A)M-oriented tools depends on the level of teachers' digital competences. Digital technologies make it possible to create an interactive educational environment in which students can apply the knowledge they have acquired to solve real-world tasks.

The rapid development of technologies in the modern world opens up new opportunities for education and learning. Among these technologies, particular attention should be paid to STE(A)M-oriented tools, which expand opportunities for interaction among participants in the educational process when implementing such relevant methods as Project-Based Learning (PBL) [3], Discovery-Based Learning, the Cooperative Learning Method, Inquiry-Based Learning, and Problem-Based Learning (Usman et al., 2022 [20]; Almulla et al., 2020 [1]; Morze et al., 2020 [14]; Makransky et al., 2023 [13]; Del Moral Pérez et al., 2023 [6]), among others.

These methods may share common elements, but each has its own characteristics and differs in its approach to organising and conducting educational activities. The key differences are considered below.

From the perspective of the focus on the process of knowledge discovery and product creation, these methods differ as follows:

- **Discovery-Based Learning:** the primary emphasis is placed on the process of self-discovery and knowledge acquisition. Students may participate in research, experimentation, and the discovery of new facts, while the product or outcome is not always the central focus;
- **PBL:** PBL focuses on students' creation of a specific product or project. Such a product may involve research, presentations, the creation of artefacts, or the solution of a particular problem;
- **Cooperative Learning Method:** focuses on collaboration and group interaction;
- **Inquiry-Based Learning:** focuses on stimulating questions and solving tasks through investigation;
- **Problem-Based Learning:** focuses on solving real-world problems through collaboration and analysis.

From the perspective of the role of the teacher and learner autonomy, the methods differ as follows:

- **Discovery-Based Learning:** provides greater learner autonomy in the research process. The teacher acts as a facilitator, creating conditions for discovery without necessarily directing the outcome. Assessment may focus more on the learning process, the development of critical thinking, and learner independence;
- **PBL:** the teacher may have greater involvement in defining the parameters and objectives of the project, assigning specific tasks, and assessing the final product. However, an element of

learner autonomy may remain, particularly in choosing the approach to project implementation. Assessment often emphasises the outcomes and quality of the product created by students, while also taking into account the process and their participation in project implementation;

- **Cooperative Learning Method:** the teacher facilitates group dynamics by ensuring equal participation and effective communication. Assessment may consider the quality of collaboration, communication, and group interaction;
- **Inquiry-Based Learning:** the teacher guides the inquiry process, helps formulate questions, and provides support in solving tasks. Assessment focuses on the research process and students' ability to formulate and answer questions;
- **Problem-Based Learning:** the teacher facilitates problem identification, guides the process, and assesses the application of knowledge in real-world scenarios. Assessment focuses on outcomes demonstrated in real-world applications and may assess the group's ability to collaborate and think critically.

When teachers use these methods, approaches to knowledge acquisition also differ. For example, Discovery-Based Learning is more focused on personal investigation and the discovery of new knowledge, during which students may independently formulate questions and search for answers. PBL, by contrast, focuses more on a specific project, enabling students to apply and implement the knowledge they have acquired when creating a product.

Although these approaches may overlap, incorporating certain elements of one method into another, they have unique characteristics and educational values. These methods differ in their approaches and emphases, but each is characterised by active student participation, promotion of autonomy, and development of critical thinking. The choice of method may depend on learning objectives, content, and desired learning outcomes, particularly when implementing STE(A)M education.

In contemporary society, the implementation of these methods should be supported and facilitated by STE(A)M-oriented tools, which can significantly improve students' learning outcomes.

Among the types of STE(A)M-oriented tools, the following can be identified:

- **Virtual and augmented reality technologies (VR/AR)** provide opportunities for immersing students in a virtual environment to simulate real-world situations (e.g., Google Expeditions, Unity, CoSpaces Edu, Google VR SDK, AltspaceVR, etc.). **Augmented Reality (AR)** adds digital elements to the real world, enhancing the perception of educational material (e.g., Zappar, Vuforia, ARKit, ARTutor, Blippar, Metaverse Studio, etc.);
- **Robotics and programming** (e.g., educational kits such as Lego Mindstorms, Arduino, Raspberry Pi, etc.) are used to study the fundamentals of programming and engineering and to create automated systems;
- **Interactive simulations and laboratories** (e.g., PhET Interactive Simulations and Labster, etc.) enable experiments to be conducted in a virtual environment, while **sensor-based laboratories** (e.g., Vernier, PASCO) enable precise real-time measurements;
- **3D modelling tools** (e.g., Tinkercad and SketchUp) enable students to create 3D models to understand the principles of engineering and design;

- **Cloud platforms and online resources** (e.g., Google Classroom, Microsoft Teams) support the organisation of the educational process, teacher–student interaction, and collaborative project editing.

At the same time, teachers' readiness to use STE(A)M-oriented tools and their self-assessment of digital competence are important for improving the educational process within the above-mentioned methods and for implementing STE(A)M education [5].

To characterise teachers' digital competence in terms of their level of readiness to use STE(A)M-oriented tools, it is necessary to consider the recommendations outlined in strategic international and national documents, such as:

- **The Concept for the Implementation of State Policy in the Field of Reforming General Secondary Education "New Ukrainian School" until 2029** [28], whose priorities include improving the quality of education, enhancing teacher training and support for the implementation of interactive and inclusive teaching methods, and modernising educational infrastructure;
- **The Digital Competence Framework for Educators (DigCompEdu)** — a document specifically developed for teachers that contains criteria for assessing digital skills in an educational context [18] and evaluates teachers' ability to use digital tools for teaching, assessment, and professional development;
- **ISTE Standards for Educators** — a document developed by the International Society for Technology in Education (ISTE) that contains standards describing key competences for educators in the digital age. It may be useful for determining teachers' readiness to use digital tools in the educational process [11];
- **The Concept for the Development of Natural and Mathematical Education (STEM Education)**, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 5 August 2020, which defines key areas of education reform, including improving the quality of learning, developing students' digital competences, integrating STEM subjects, and supporting teachers in implementing innovative teaching methods [27].

In addition to the above, specialised tests for assessing and self-assessing teachers' digital competence may also be useful.

The following tests deserve attention: **"Digigram for Teachers"** (https://osvita.diia.gov.ua/digigram), offered by the **Diia** web portal (an abbreviation for "State and Me"), developed by the Ministry of Digital Transformation of Ukraine and designed to take approximately 30–40 minutes; and **"SELFIEforTEACHERS"** (https://educators-go-digital.jrc.ec.europa.eu/about), developed by the European Commission together with a group of education experts from across Europe and designed to take approximately 30 minutes.

The **"Digigram for Teachers"** test covers the following areas:

- **Teacher in a Digital Society**, which includes an understanding of the concepts of "digital society," "e-government," "Electronic School," "e-learning," and "Security in a Digital Society";
- **Professional Development**, which involves assessing teachers' professional communication, their ability to collaborate in a digital educational environment, and their skills and abilities

to continuously develop professional competences related to the use of new digital technologies;

- **Use and Analysis of Digital Resources**, which includes selecting digital resources, creating and modifying digital educational resources, managing and sharing digital educational resources, and protecting digital resources;
- **Teaching and Assessment of Students**, which involves assessing the organisation and management of students' educational process, organising interactive and active learning, including student collaboration, ensuring individualisation and differentiation of learning, inclusive learning, analysing and interpreting digital data, providing feedback, assessing students, and organising student self-monitoring;
- **Development of Students' Digital Competence**, whereby teachers are expected to support the development of students' information and media literacy, responsible use of digital technologies and services, and students' ability to solve problems using digital technologies and services.

According to these areas, teachers' digital competence is assessed according to levels A1 and A2, corresponding to the **basic level**; B1 and B2, corresponding to the **intermediate level**; and C1 and C2, corresponding to the **advanced level**.

Upon completion of the test, the teacher receives an electronic certificate (Figure 2.1) confirming their level of digital competence at the time they completed the test tasks.

Figure 2.1. Example of a certificate issued to a teacher after completing the "Digigram for Teachers" test

The **"SELFIE for TEACHERS"** test addresses the use of technologies in the following areas:

- **Professional Communication and Collaboration**, which assesses the level at which teachers can use digital technologies in their professional practice, access information, develop their teaching and learning practice, use technologies to communicate with and support students and parents, and share information and learn with colleagues and other people outside the school;
- **Finding and Creating Digital Resources**, which encompasses teachers' ability to effectively identify resources that best meet their needs, teaching style, and students' needs; modify and adapt resources to their specific requirements or create new ones; responsibly share digital resources; protect confidential data; manage content ethically; and respect copyright rules;
- **Teaching Practice**, which encompasses the ability to create and organise learning using digital technologies to support educational activities and provide meaningful teaching and learning experiences;
- **Assessment of Students**, which involves teachers' use of digital technologies to collect data in order to better support and assess students, while also enabling them to reflect on and adapt their teaching practice;
- **Enhancing Students' Digital Competence**, which involves determining teachers' level of proficiency in using digital technologies to support and facilitate the formation and development of their students' digital competence.

Digital technologies can be used by teachers to personalise learning and adapt it to individual students' levels, interests, and needs. However, it is important to avoid reinforcing inequalities, for example, in relation to students' access to technologies or lack of skills. Accessibility for all students is extremely important, including for those with special educational needs.

As a result of completing the **"SELFIE for TEACHERS"** test, teachers receive a certificate (Figure 2.2).

Figure 2.2. Example of a "SELFIE for TEACHERS" certificate

The “SELFIE for TEACHERS” certificate is not of particular significance for the school in which the teacher works. What is important is the explanation of the user’s responses (Figures 2.3a, b) and the provision of recommendations for improving their digital competence.

Figure 2.3(a). Example of an overall conclusion based on the results of a teacher’s completion of the “SELFIE for TEACHERS” test

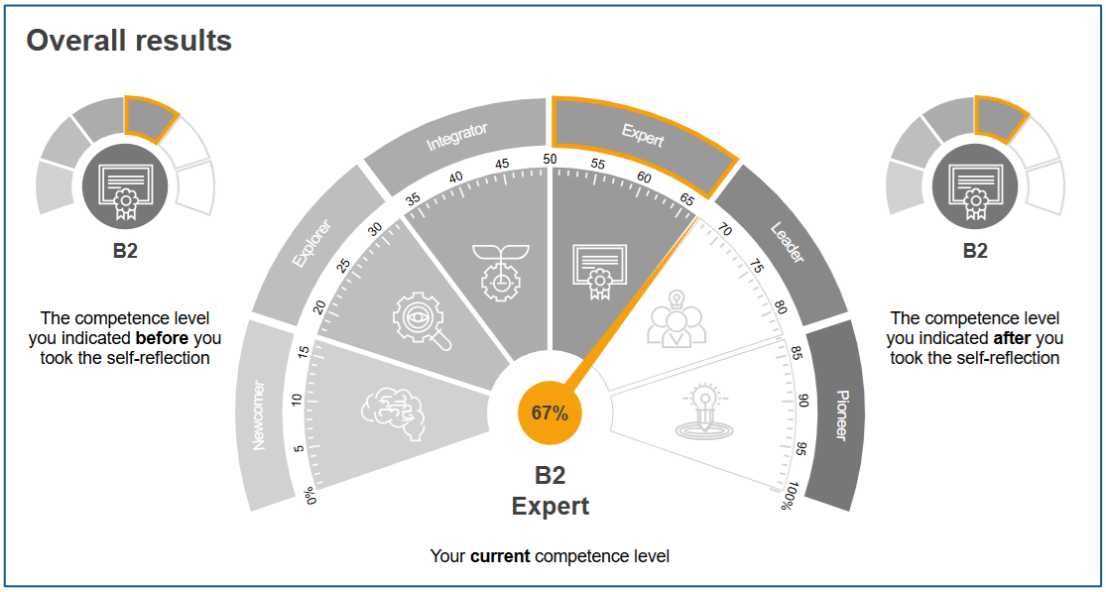
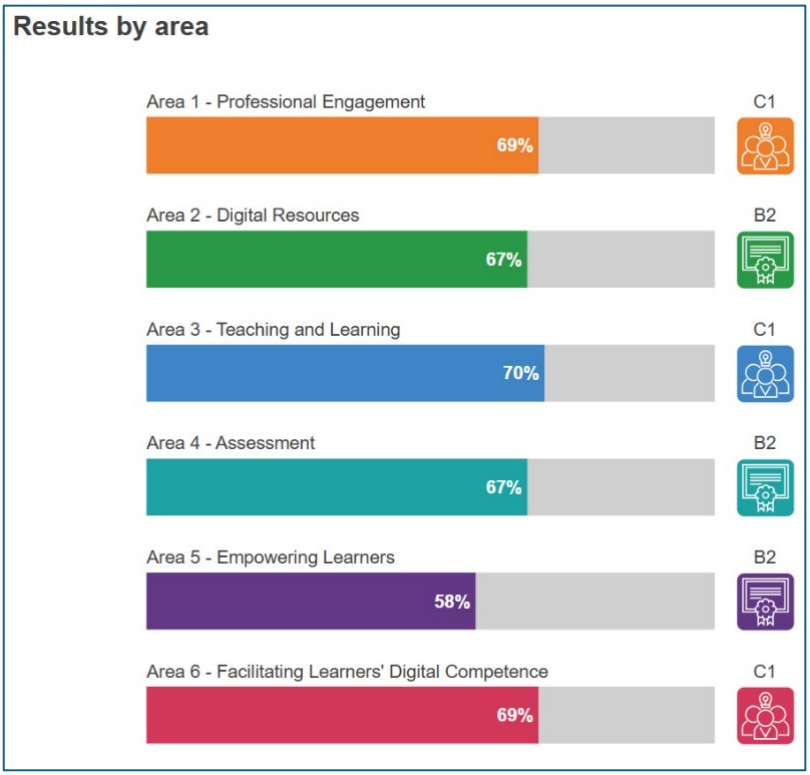


Figure 2.3(b). Example of a conclusion based on the results of a teacher’s completion of the “SELFIE for TEACHERS” test for each section of the test



Each teacher's response to the test tasks is accompanied by an explanation and recommendations (Figure 2.4).

Figure 2.4. Example of a page fragment providing recommendations to a teacher concerning the "Teaching and Learning" test item

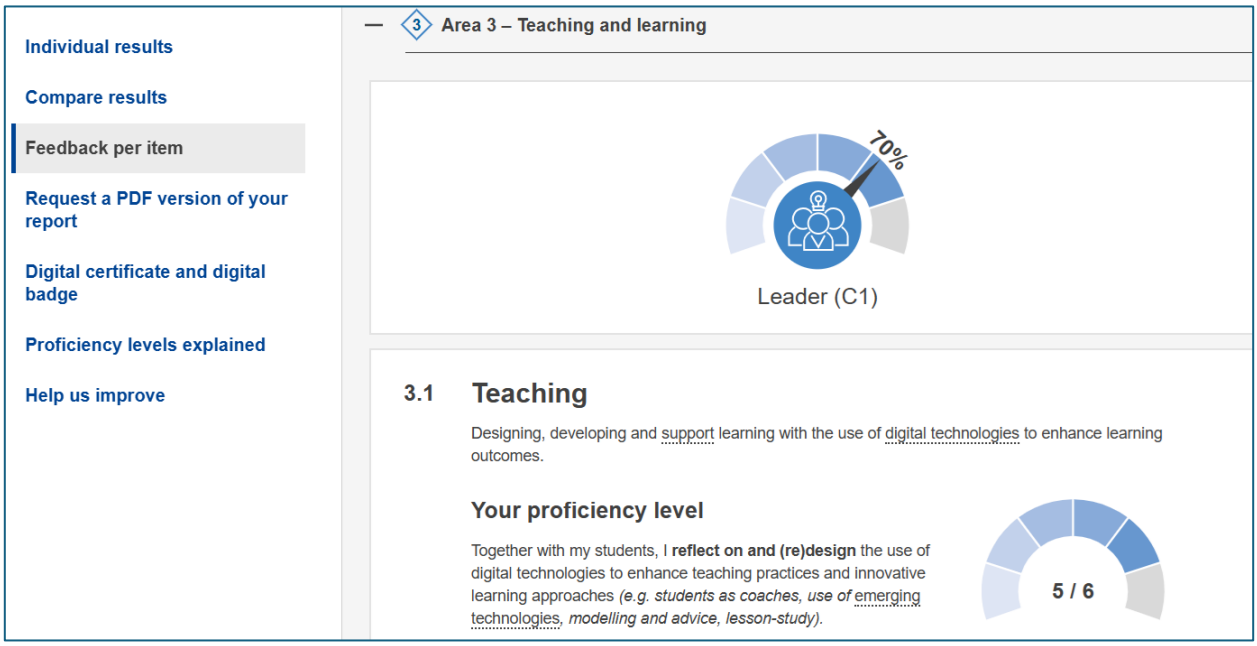


Figure 2.4 presents a fragment of a page containing recommendations for a teacher concerning the "Teaching and Learning" test item. An example of the recommendations provided is presented below.

The "Teaching and Learning" item showed that the teacher's knowledge level was 5 out of 6, and the following recommendations were therefore provided:

"Consider how you can work with your students to adjust your teaching and learning design in order to encourage students to contribute to improving your teaching practice and their approaches to learning. Consider embedding the consistent use of technology in activities such as engaging students as instructors, using emerging technologies, modelling and mentoring, and classroom learning. Reflection is key to this. Your students should gain confidence in their ability to help select and adapt technology according to learning requirements. Consider opportunities such as online seminars, peer support in learning technology-enhanced design, microlearning and collaborative learning, and reflective discussions on the effectiveness of digital technology use. Engage in technology-supported networks with other schools and education stakeholders at local, national, and international levels."

Thus, based on the above, we propose focusing on the following key indicators for characterising teachers' digital competence in terms of their readiness to use STE(A)M-oriented tools:

- **Digital competence**, i.e. the level of proficiency in digital tools (use of software and multimedia content, educational platforms, working with data, etc.);

- **Methodological training**, namely the ability to integrate the STEAM approach into the educational process using digital technologies (creation of didactic materials, visualisation of learning materials, etc.);
- **Innovation**, i.e. readiness to implement new digital technologies and adopt a creative approach to developing STEAM projects;
- **Adaptability**, encompassing teachers' ability to quickly master new technologies and adapt lessons to digital changes;
- **Communication skills**, i.e. the ability to interact with students in a digital environment and organise teamwork;
- **Attitudes towards digital technologies**, namely the general interest of teachers and students in using electronic educational resources to improve learning effectiveness and professional development.

Results of the Assessment (Self-Assessment) of Teachers' Readiness to Use AI for STEAM Learning

The integration of AR and VR into STEAM educational projects opens up opportunities for dynamic and multidimensional learning. Teachers were asked to indicate the digital tools (VR/AR) they use and those they had used when implementing STEAM projects (Table 2.1).

In the 2023 survey, conducted using Google Forms, 87 teachers participated. The survey was intended to demonstrate teachers' readiness to apply digital technologies for conducting and supporting STEAM education.

Table 2.1. Results of the teacher survey on readiness to use digital tools when implementing STEAM projects

Source: authors' own research

VR/AR tool	I do not know this tool (%) / number of respondents	I use this tool (%) / number of respondents	I have used this tool when implementing STEAM projects (%) / number of respondents	I know this tool but do not use it (%) / number of respondents	Comments and recommendations
Unity/VR	36.8% / 32	32% / 28	17% / 15	37% / 27	Unity is a powerful engine for developing games and virtual-reality applications. It is difficult to use; therefore, training is required.
Google Expeditions/VR	–	67% / 59	39% / 34	32% / 28	–

Google VR SDK	16% / 14	68% / 60	55% / 48	15% / 13	–
ARCore (for Android) and ARKit (for iOS)	36.8% / 32	32% / 28	17% / 15	37% / 27	–
Vuforia/AR	36.8% / 32	32% / 28	17% / 15	37% / 27	This resource is paid for and therefore cannot always be used with students in the classroom.
Zappar/AR	36.8% / 32	–	–	63% / 55	Zappar is a tool for creating AR annotations and displaying interactive content using mobile devices.
CoSpaces Edu/VR	–	36.8% / 32	30% / 26	63% / 55	CoSpaces Edu is a web platform that allows teachers and students to create virtual worlds and interactive VR lessons without programming.
AltspaceVR	16% / 14	27% / 24	9% / 8	56% / 49	–
Metaverse Studio/AR	21% / 18	79% / 69	61% / 53	–	Metaverse Studio is a platform for creating AR applications and interactive games without programming.
Blippar/VR and AR	21% / 18	79% / 69	42% / 37	–	–
CoSpaces Edu Merge Cube/AR	–	65% / 57	39% / 34	34% / 30	–
Mozilla Hubs/VR and AR	54% / 47	–	–	46% / 40	–
SketchUp/ VR and AR	36.8% / 32	32% / 28	17% / 15	37% / 27	–
EasyAR	13.8% / 12	25% / 22	11% / 10	61% / 53	–
Spark AR	13.8% / 12	–	–	86% / 75	The tool's function is to create masks for Instagram, which is rather

					specific and may be used for a limited range of tasks in STEAM projects.
Other	100% / 87	–	–	–	Teachers who participated in the survey use AR and VR to conduct research and experiments within individual school subjects.

Table 2.1 presents the results of the teacher survey concerning awareness of digital tools. Teachers demonstrate different levels of familiarity with and use of virtual reality (VR) and augmented reality (AR) tools.

For example, certain tools, such as Google Expeditions, demonstrate a high level of use compared with tools such as Mozilla Hubs, which have a lower rate of use among teachers.

The survey results indicate the level of popularity of the tools and the specific ways in which each tool is used in the context of STEAM project implementation.

In particular, the response **"I do not know this tool"** indicates the need to develop targeted training programmes and initiatives aimed at raising teachers' awareness. Thus, 36.8% (32) of respondents indicated that they did not know tools such as Unity/VR, Vuforia/AR, Zappar/AR, ARCore (for Android) and ARKit (for iOS), CoSpaces Edu/VR, and SketchUp/VR and AR. Google VR SDK was indicated by 16% (14) of respondents; Metaverse Studio/AR and Blippar/VR and AR were indicated by 21% (18 respondents); EasyAR and Spark AR were indicated by 13.8% (12 respondents) (Figure 2.5).

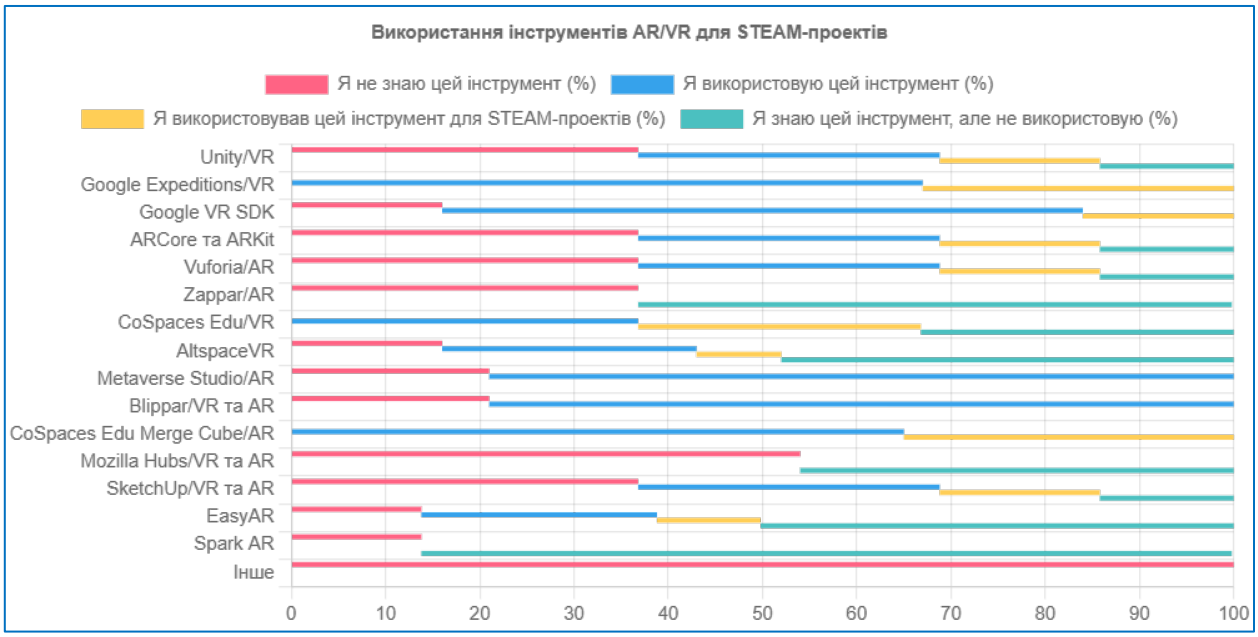


Fig. 2.5. Diagram showing the level of use of AR/VR tools for STEAM projects (source: own research)

The prevalence of responses to **"I have used this tool when implementing STEAM projects"** indicates that tools such as Metaverse Studio, Google VR SDK, Blippar, Google Expeditions, and

CoSpaces Edu are popular for STEAM projects: Metaverse Studio/AR — 61% (53 respondents); Google VR SDK — 55% (48 respondents); Blippar/VR and AR — 42% (37 respondents); Google Expeditions/VR — 39% (34 respondents); and CoSpaces Edu — 30% (26 respondents).

Comments from teachers emphasising the interactive and engaging nature of tools such as Zappar, CoSpaces Edu, and Metaverse Studio indicate that the proportion of interactive learning in educational institutions is currently increasing.

Teachers also use tools in both VR and AR environments, indicating potential for interdisciplinary projects. This interdisciplinary approach is consistent with the holistic objectives of STEAM education.

CHAPTER 3. TEACHERS' COMPETENCE IN THE USE OF ARTIFICIAL INTELLIGENCE: INTERNATIONAL APPROACHES TO ASSESSMENT

The requirements placed on teachers are constantly increasing, which calls for the development of an increasingly complex set of professional competences. In particular, the rapid pace of digital technology development creates a strong impetus for educators to enhance their digital competence. Realising the potential educational benefits of artificial intelligence (AI) and the widespread use of digital data in general requires the active and meaningful participation of teachers and school leaders. This, in turn, requires the development of the necessary AI literacy and data literacy to assess the full potential of such systems while being aware of their shortcomings and limitations.

What teachers should know, understand, and be able to do, as well as which attitudes may support them, are among the questions addressed by the team of the European Digital Education Hub (EDEH) on artificial intelligence in education.

The European Commission has defined a policy (strategy) for the use of artificial intelligence systems that should primarily focus on protecting children, ensuring fairness in meeting their needs and rights, and enabling them to participate in a world of artificial intelligence by contributing to the development and use of AI. This is addressed by UNICEF in its *Policy Guidance on AI for Children* (2021). On this basis, nine requirements for child-centred AI were developed:

- supporting children's development and well-being;
- ensuring inclusion of children and for children;
- prioritising fairness and non-discrimination for children;
- protecting children's data and privacy;
- ensuring safety for children;
- ensuring transparency, explainability, and accountability to and for children;
- empowering governments and raising the awareness of organisations (companies) regarding AI and children's rights;
- preparing children for current and future developments in AI;
- creating an enabling environment for child-centred AI.

These requirements are directly relevant to the educational context and can be used to govern and deploy future AI-based digital applications in education. In addition, attention should be paid to empowering children and creating a safe environment for them.

Within the Erasmus+ programme (2021–2027), the European Commission launched the European Digital Education Hub (EDEH), which enabled a consortium of 13 organisations to cooperate under a service contract with the European Education and Culture Executive Agency (EACEA) in the field of developing teachers' digital competences related to the use of AI.

The European Commission also established an online resource for educators — the European Digital Education Hub (Figure 3.1). Within this project, some initiatives were implemented, making it

possible to distinguish teachers' competences according to three segments based on the principles of **"for," "with," and "about" artificial intelligence**, namely:

- **"Learning for" AI** involves competences for all citizens, including teachers and students, to work confidently, critically, and safely with AI systems and to acquire the knowledge, skills, and attitudes necessary for life in a world surrounded and shaped by AI;
- **"Learning with" AI** focuses on how AI systems can be used to achieve educational objectives, including the use of pedagogical judgement concerning when they should be used, as well as knowledge of the functioning of basic algorithms, pedagogical models, and data;
- **"Learning about" AI** is the more technical component, focused on teaching pupils and students the fundamentals of AI. It is generally part of AI literacy and should encompass both the technological and human aspects of AI, organised according to the learner's age. Knowledge of the fundamentals of AI is essential for preparing young people for the labour market, regardless of their future career.

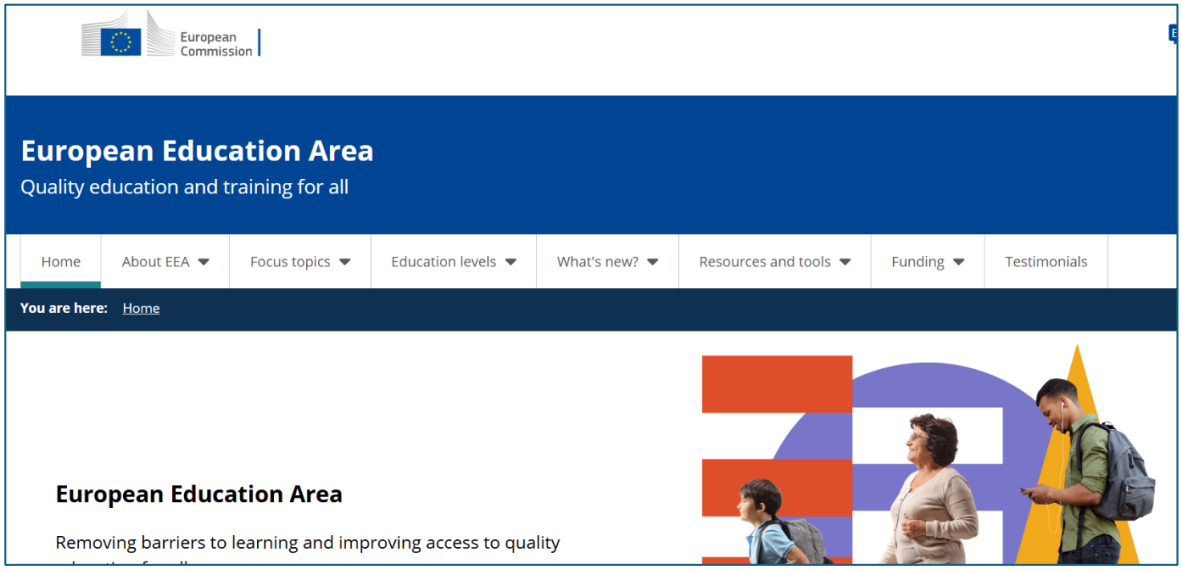


Figure 3.1. Screenshot of the European Digital Education Hub webpage
Source: https://education.ec.europa.eu/

In 2022, the European Commission published *DigComp 2.2: The Digital Competence Framework for Citizens* (DigComp 2.2), containing new examples of knowledge, skills, and attitudes for the confident, critical, and responsible use of digital technologies for learning, work, and participation in society.

DigComp is a European-wide reference framework for improving citizens' digital competence and supporting the development of educational policies aimed at fostering digital competence, as well as for planning educational and training initiatives designed to improve the digital competence of specific target groups.

In addition to the general digital skills already included in previous versions of DigComp, the new version (2.2) contains more than 30 examples related to interaction with AI systems. The framework also includes an appendix (pages 77–82) describing 73 examples that may help citizens when interacting with AI systems. These include questions such as: What do AI systems do and what do they not do? How do AI systems work? What challenges exist, and what are the ethics of AI?

To assess teachers' competences for the use of AI, it is necessary to examine in detail the examples proposed by the European Commission that may serve as indicators. Using the digital competence framework supplemented with AI descriptors, several indicators and examples of teachers' use of this instrument have been developed within five areas of digital competence:

- information and digital literacy;
- communication and collaboration;
- digital content creation;
- safety;
- problem-solving.

Table 3.1. Description of descriptors and examples within the "learning for" AI approach *Source: [9]*

Descriptors	**Examples within the "learning for" AI approach (DigComp 2.2)**
Information and digital literacy	**4.** Understands that search engines, social media, and content platforms often use AI algorithms to generate responses adapted to individual users (for example, users continue to see similar results or content). This is often referred to as "personalisation." **5.** Understands that AI algorithms operate in ways that are generally not visible or easily understandable to users. This is often referred to as "black-box" decision-making, as it may be impossible to trace how and why an algorithm makes a particular recommendation or prediction. **14.** Weighs the advantages and disadvantages of using AI-powered search engines (for example, although they may help users find the information they need, they may compromise privacy and personal data or expose users to commercial interests). **22.** Understands that the data on which AI depends may contain biases. If this is the case, such biases may become automated and amplified through AI. For example, search results concerning occupations may include stereotypes about male or female work (e.g., male bus drivers, female salespersons). **27.** Is able to recognise that some AI algorithms may reinforce existing views in the digital environment by creating "echo chambers" or "filter bubbles" (for example, if a social media feed supports a particular political ideology, additional recommendations may reinforce that ideology without exposing the user to opposing arguments).
Communication and collaboration	**50.** Knows how to identify signs indicating whether one is communicating with a person or an AI-based conversational agent (for example, when using text-based or voice chatbots).

	56. Understands that everything shared publicly on the Internet (e.g., images, videos, sounds) may be used to train AI systems. For example, commercial software developers creating AI-based facial-recognition systems may use personal images published online (such as family photographs) to train and improve the software's ability to automatically recognise these people in other images, which may be undesirable (e.g., it may constitute a privacy violation). **70.** Recognises that while the application of AI systems in many areas is generally not controversial (e.g., AI that helps prevent climate change), AI that directly interacts with people and makes decisions concerning their lives can often be controversial (e.g., software for sorting CVs during recruitment procedures or exam scoring that may determine access to education). **105.** Understands that AI systems collect and process different types of user data (e.g., personal, behavioural, and contextual data) to create user profiles that are subsequently used, for example, to predict what users may want to see or do next (e.g., advertisements, recommendations, or services). **113.** Knows how to modify user configurations (e.g., in applications, software, or digital platforms) to enable, prevent, or moderate the tracking, collection, or analysis of data by an AI system (e.g., preventing a mobile phone from tracking the user's location). **117.** Identifies both positive and negative consequences of the use of data (e.g., collection, coding, and processing), particularly personal data, by AI-driven digital technologies such as applications and online services.
Digital content creation	**119.** Knows that AI systems can be used to automatically create digital content (e.g., texts, news, essays, tweets, music, and images) using existing digital content as a source. Such content may be difficult to distinguish from content created by humans. **134.** Knows how to incorporate AI-edited/processed digital content into their own work (e.g., incorporating AI-generated melodies into their own musical composition). Such use of AI may be controversial because it raises questions about the role of AI in artistic works and, for example, about whom credit should be attributed to.
Safety	**187.** Weighs the benefits and risks before allowing third parties to process personal data (e.g., recognising that a voice assistant on a smartphone used to issue commands to a robotic vacuum cleaner may provide third parties — companies, governments, or cybercriminals — with access to data). **216.** Considers the ethical implications of AI systems throughout their entire life cycle. These include environmental impacts (the consequences of producing digital devices and services for the environment) and societal impacts, such as the platformisation of work and algorithmic management that

	may undermine privacy or workers' rights, as well as the use of low-cost labour for labelling images used to train AI systems.
Problem-solving	**221.** Understands that AI is a product of human intelligence and decision-making (i.e., people select, clean, and code data; develop algorithms; train models; manage them; and apply human values to their outputs) and therefore does not exist independently of humans. **231.** Understands that AI-driven speech technology enables the use of voice commands that can improve the accessibility of digital tools and devices (e.g., for people with mobility or visual impairments, limited cognitive abilities, or language or learning difficulties). However, languages spoken by smaller populations are often unavailable or work less effectively because of commercial priorities. **233.** Knows how and when to use machine translation solutions (e.g., Google Translate, DeepL) and simultaneous translation applications (e.g., iTranslate) to obtain an approximate understanding of a document or conversation. However, also understands that when content requires accurate translation (e.g., in healthcare, trade, or diplomacy), a more precise translation may be necessary. **246.** Is open to participating in collaborative processes for the co-design and co-creation of new products and services based on AI systems to support and enhance citizens' participation in society. **255.** Is willing to continue learning, receive training, and stay informed about AI (e.g., understand how AI algorithms work; understand the extent to which automated decision-making may be biased; distinguish realistic from unrealistic AI; and understand the difference between artificial narrow intelligence — that is, contemporary AI capable of performing narrow tasks such as games — and artificial general intelligence, i.e., AI that surpasses human intelligence, which remains science fiction).

Assessment within the "Learning with" AI Approach

Assessment within the **"learning with" AI** approach is proposed to be based on the *Ethical Guidelines on the Use of Artificial Intelligence (AI) and Data in Teaching and Learning for Educators*, developed by the European Commission in 2022.

These ethical guidelines on the use of AI and data in teaching and learning were developed to help educators understand the potential that the use of AI and data may have in education and to raise awareness of possible risks, positive and critical engagement, and the ethical use of AI systems.

The section **"New competences for the ethical use of AI and data"** proposes descriptions of new competence indicators for teachers and school leaders concerning the ethical use of AI and data in teaching and learning. These indicators are organised according to the six areas previously identified

in the **European Framework for the Digital Competence of Educators (DigCompEdu)**, which supports the development of specific digital competences for educators in EU countries.

Description of indicators of specific competences for the use of AI within the "learning with" AI approach. *Source: [8]*

Area 1. Professional Engagement

Able to critically describe the positive and negative impact of AI and the use of data in education

- Actively participates in continuous professional learning on AI and learning analytics and their ethical use.
- Is able to provide examples of AI systems and describe their relevance.
- Knows how the ethical impact of AI systems is assessed at school.
- Knows how to initiate and promote strategies at school and in the wider community that foster the ethical and responsible use of AI and data.

Understands the basics of AI and learning analytics

- Understands that AI algorithms operate in ways that are generally not visible or easily understandable to users.
- Is able to interact with and provide feedback to an AI system in order to influence subsequent actions.
- Understands that sensors used in many digital technologies and applications generate large amounts of data, including personal data, which can be used to train AI systems.
- Is familiar with EU ethical principles concerning AI and self-assessment tools.

Area 2. Digital Resources

Data management

- Knows about different forms of personal data used in education and learning.
- Understands responsibilities related to ensuring data security and privacy.
- Knows that the processing of personal data is regulated by national rules and EU regulations, including the General Data Protection Regulation (GDPR).
- Knows that the processing of personal data generally cannot be based on user consent in compulsory education.
- Knows who has access to students' data, how access is controlled, and how long data are stored.
- Knows that all EU citizens have the right not to be subject to fully automated decision-making.
- Is able to provide examples of confidential data, including biometric data.
- Is able to weigh the benefits and risks before allowing third parties to process personal data, particularly when using AI systems.

AI governance

- Knows that AI systems are subject to national and EU regulation (including the forthcoming AI Act).

- Is able to explain the risk-based approach of the AI Act.
- Knows high-risk use cases of AI in education and the relevant requirements under the proposed AI Act.
- Knows how to incorporate AI-edited/processed digital content into their own work and how such work should be assessed.
- Is able to explain key principles of data quality in AI systems.

Area 3. Teaching and Learning

Learning models

- Knows that AI systems implement the designer's understanding of what learning is and how learning can be measured; can explain the key pedagogical assumptions underlying a given digital learning system.

Educational objectives

- Knows how a given digital system addresses different social objectives of education (qualification, socialisation, and subjectification).

Human agency

- Is able to consider the impact of an AI system on teacher autonomy, professional development, and educational innovation.
- Considers sources of unacceptable bias in data-driven AI.

Fairness

- Considers risks related to emotional dependence and student self-assessment when using interactive AI systems and learning analytics.

Humanity

- Is able to consider the impact of AI and the use of data on the student community.
- Is confident in discussing the ethical and legal aspects of AI and how they affect the use of technology.
- Participates in the development of teaching practices using AI and data.
- Can explain how ethical principles and values are considered and discussed during the co-design and co-creation of teaching practices that use AI and data (related to learning design).

Area 4. Assessment

Individual differences

- Understands that students respond differently to automated feedback.

Algorithmic bias

- Considers sources of unacceptable bias in AI systems and ways to mitigate it.

Cognitive orientation

- Understands that AI systems assess student progress based on predefined, subject-oriented knowledge models.
- Understands that most AI systems do not assess collaboration, social skills, or creativity.

New ways of misusing technology

- Knows common ways of manipulating AI-based assessment.

Area 5. Empowering Students

AI responds to students' diverse learning needs

- Knows how personalised learning systems can adapt their behaviour (content, learning pathway, and pedagogical approach).
- Is able to explain how a particular system can benefit all students regardless of their cognitive, cultural, economic, or physical differences.
- Understands that digital learning systems treat different groups of students differently.
- Is able to consider the impact on the development of students' self-efficacy, self-assessment, thinking, and cognitive and emotional self-regulation skills.

Justified choice

- Knows that AI and the use of data may benefit some students more than others.
- Is able to explain what evidence was used to justify the deployment of a particular AI system in the classroom.
- Recognises the need to continuously monitor the outcomes of AI use and learn from unexpected results.

Area 6. Facilitating Students' Digital Competence

AI and the ethics of learning analytics

- Is able to use AI projects and deployments to help students learn about the ethics of AI and the use of data in education and learning.

Specific teacher competences are also covered by the **Digital Competence Framework for Educators (DigCompEdu Framework, 2017)**, which aims to describe digital competences for the effective and responsible use, creation, and sharing of digital resources for learning, while also focusing on the strategy and potential of using digital technologies for student-centred teaching and learning.

Based on this framework, the free self-reflection tool **SELFIE for TEACHERS** was launched in October 2021 for primary and secondary school teachers. It includes AI-related competences and a number of questions that encourage educators to reflect on the use of AI tools in education.

The Council of Europe report *Artificial Intelligence and Education – A Critical View through the Lens of Human Rights, Democracy and the Rule of Law* recommends supporting and encouraging all citizens to attain a certain level of AI literacy.

It is important to possess knowledge, skills, and values focused on the development, implementation, and use of AI technologies. AI literacy should encompass both the technical and human aspects of

AI, including how AI works and its impact on people's lives, particularly cognitive abilities, privacy, and freedom of choice. Without an understanding of the impact of AI on people, learning about what AI does and the digital competences of modern individuals are not sufficient.

Teachers' competences should primarily be based on students' needs. Therefore, it is necessary to determine which skills students should possess at different levels of education in relation to the use of AI.

One project that can be used as a resource for determining teachers' competence on the basis of students' competences is the **"AI4K12 Five Big Ideas for AI Education"** project. The *Artificial Intelligence (AI) for K-12* initiative (AI4K12) is jointly sponsored by AAAI and CSTA. The key ideas presented in this initiative provide a comprehensive overview of AI adapted to the understanding of school-age children, including:

- **Perception:** computers perceive the world through sensors that collect information from their surroundings.
- **Representation and reasoning:** AI agents create and maintain internal models of the world, which they use to make decisions and solve problems.
- **Learning:** machines can learn from data and improve their performance over time.
- **Natural interaction:** intelligent agents require a broad range of knowledge to interact naturally with people, including language, social skills, and emotional intelligence.
- **Societal impact:** AI can affect society both positively and negatively, and it is important to consider the ethical implications of its use.

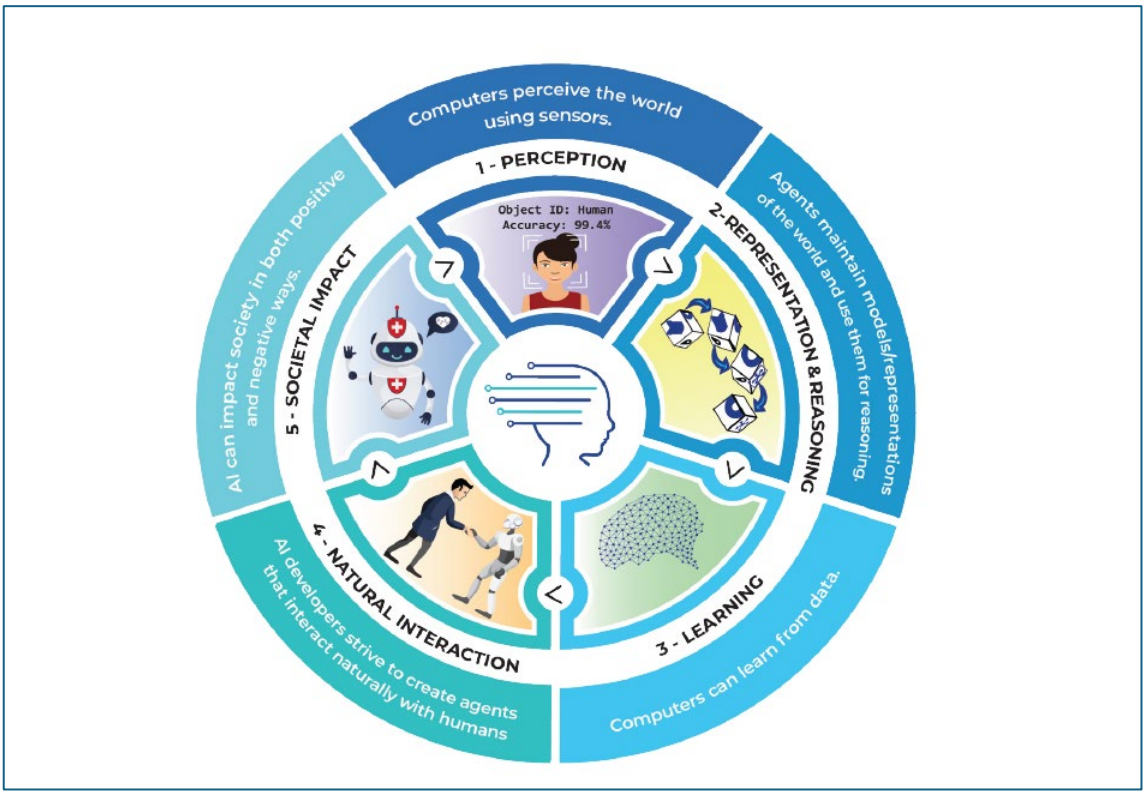


Figure 3.2. AI4K12 Grade Band Progression Chart
Source: "Grade Band Progression Charts" by the AI4K12 Initiative, licensed under CC BY-NC-SA 4.0

The diagram illustrates the interrelationships between perception and learning concerning the use of AI, combined with natural interaction and societal impact, which teachers should take into account in their work with students.

To support students at the K–12 level, the above-mentioned AI4K12 recommendations, *"Five Big Ideas for AI Education,"* propose the use of transparent AI demonstrations that help students understand artificial intelligence.

To develop AI-related competencies in students, the EDEH group has proposed several areas of relevance for teacher development [9]. These areas are aimed at developing AI-related competencies in teachers and include the following positions in the known digital competency areas (Table 3.2).

Table 3.2. Description of areas aimed at developing competencies in the field of AI use (Source [9]).

Basic Digital Skills	• Content Creation • Cloud Usage • Data Analysis and Representation • Collaboration and Communication Tools
Computational Thinking	• Design Thinking • Problem Solving • Block Programming • Text Programming
Mathematics	• Basic Statistics • Basic Probability
Existing AI Applications	• Provide a Realistic View of AI • Get Updates on Real-World AI Uses • Ethics Based on Real-World Cases • Legal Issues and Data Privacy
Special AI Topics	• Perception and Activation • Perception and Reasoning • Machine Learning • Collective Intelligence

CHAPTER 4. RESULTS OF TEACHERS' SELF-ASSESSMENT OF DIGITAL COMPETENCE IN TERMS OF THEIR READINESS TO USE DIGITAL TOOLS

In 2024, as part of a teacher survey conducted by the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, respondents were asked to answer a separate block of questions entitled **"Teacher's Digital Competence."** This block was designed to enable teaching staff to conduct a self-assessment of their level of digital competence [41].

This part of the questionnaire has been used as a separate tool for teachers' self-assessment of digital competence for several years (2021, 2022, 2023, and 2024) [16]. The tool was first used by the survey authors in Ukraine in 2021 during the COVID-19 quarantine [12]. The questions in the questionnaire were developed on the basis of international approaches, in particular the document *Digital Competence Framework for Citizens: Eight Proficiency Levels with Examples of Use* (DigComp 2.1: Digital Competence Framework for Citizens) [4] and DigComp 2.2 [10].

PURPOSE OF USING THE SELF-ASSESSMENT TOOL

The purpose is to provide teachers with the freedom to choose self-assessment tools and subsequently use them for their own professional needs, to develop a professional self-improvement and self-development trajectory.

The scope of application of the tool includes the system of postgraduate teacher education, general secondary education institutions, and research institutions studying the development of professional competences among teaching staff.

The following criteria were applied:

- **Relevance and future potential** — the need to increase the level of digital competence, compliance with the needs and interests of teachers and general secondary education institutions, and opportunities for practical application, including within the postgraduate teacher education system;
- **Sufficient theoretical level and research-based nature** — assessment of teachers' digital competence is considered at the current level of development of pedagogical science and is based on EU framework documents;
- **Novelty and progressiveness** — introduction of new elements into teachers' professional self-improvement and new self-assessment models related to the use of ICT;
- **Correspondence to the professional characteristics of the target audience** — alignment with teachers' professional development programmes and professional competence standards;
- **Effectiveness and impact** — orientation towards the development of digital competence and teachers' professional growth;
- **Practical application** — availability of experience in using ICT.

RESULTS OF THE 2023 SURVEY

The block of questions entitled **"Teacher's Digital Competence"** was designed to enable teaching staff to conduct a self-assessment of their level of digital competence. This part of the questionnaire constitutes a separate tool for teachers' self-assessment of digital competence. The tool was first used in Ukraine in 2021 during the COVID-19 quarantine [12].

The questionnaire was developed on the basis of international approaches, in particular the document *Digital Competence Framework for Citizens: Eight Proficiency Levels with Examples of Use* (DigComp 2.1: Digital Competence Framework for Citizens) [4].

The Digital Competence Framework includes the following levels: **basic user, independent user, and professional user**. It defines five areas (categories) of digital competence:

6. information and digital literacy;
7. communication and collaboration;
8. digital content creation;
9. safety;
10. problem-solving.

The self-assessment conducted within this study was focused specifically on these areas and levels.

Information and Digital Literacy

The **Information and Digital Literacy** area covers skills related to searching for, evaluating, and storing information.

Ability to Search for Information

Regarding the ability to search for and store information, the following responses were obtained (Figure 4.1, see Appendix 5):

- **34.5%** of respondents indicated that they can search for information on the Internet using a search engine, corresponding to the **basic user** level;
- **45.6%** indicated that they can use different search engines to find information, corresponding to the **independent user** level;
- **19.8%** indicated that they can use advanced search strategies to find reliable information on the Internet, for example, by using web feeds, corresponding to the **professional user** level.

Ability to Assess the Reliability of Information

Regarding the ability to assess the reliability of information during a search (Figure 4.2, see Appendix 5):

- **31.9%** of respondents indicated that they know that not all information available online is reliable, corresponding to the **basic user** level;
- **24.8%** indicated that they use certain filters when searching to compare and assess the reliability of the information they find, corresponding to the **independent user** level;

- **43.3%** indicated that they can use a range of criteria to find reliable information on the Internet, corresponding to the **professional user** level.

Ability to Store Information Found

Regarding the ability to store information found (Figure 4.3, see Appendix 5):

- **26.9%** of respondents indicated that they can save files or content and use them, corresponding to the **basic user** level;
- **31.9%** indicated that they classify information systematically using folders and create backups of files and their collections, corresponding to the **independent user** level;
- **41.2%** indicated that they can save information found on the Internet in different formats (text, audio, and video) and can store information in the cloud, corresponding to the **professional user** level.

Communication and Collaboration

The **Communication and Collaboration** area concerns communication and collaboration, as well as the use of digital tools to access and use online services.

Ability to Communicate Using Different Communication Tools

Regarding the ability to communicate using different communication tools (Figure 4.4, see Appendix 5):

- **18.9%** of respondents indicated that they can communicate with other users using calling and messaging services, corresponding to the **basic user** level;
- **20.7%** indicated that they can use advanced functions of several communication tools (e.g., Skype and file-sharing tools), corresponding to the **independent user** level;
- **60.5%** indicated that they actively use a wide range of communication tools (email, chat, SMS, instant messaging, blogs, microblogs, and social networks) for online communication, corresponding to the **professional user** level.

Ability to Create and Manage Content Using Collaboration Tools

Regarding the ability to create and manage content using collaboration tools (Figure 4.5, see Appendix 5):

- **28.5%** of respondents indicated that they can share files and content using simple tools, corresponding to the **basic user** level;
- **50.1%** indicated that they can use collaboration tools and share, for example, shared documents/files created by others, corresponding to the **independent user** level;
- **21.4%** indicated that they can create and manage content using collaboration tools (e.g., project management systems and online spreadsheets), corresponding to the **professional user** level.

Ability to Use Online Services

Regarding the ability to use online services (Figure 4.6, see Appendix 5):

- **24.1%** of respondents indicated that they know how to use online services (e.g., electronic banking, e-government, electronic healthcare services), corresponding to the **basic user** level;
- **36.8%** indicated that they use the functions of online services (e.g., public services, electronic banking, online shops), corresponding to the **independent user** level;
- **39.1%** indicated that they actively use various functions of several online services (e.g., public services, electronic banking, online shops), corresponding to the **professional user** level.

Ability to Use Online Collaboration Tools

Regarding knowledge of and the ability to use online collaboration tools (Figure 4.7, see Appendix 5):

- **40.7%** of respondents indicated that they use social networks and are aware of online collaboration tools, corresponding to the **basic user** level;
- **24.4%** indicated that they share knowledge with other users on the Internet (e.g., through social-network tools or online communities), corresponding to the **independent user** level;
- **34.9%** indicated that they use additional functions of communication tools (e.g., videoconferencing, data exchange, and sharing), corresponding to the **professional user** level.

Digital Content Creation

The **Digital Content Creation** area covers the ability to create, edit, and manage multimedia content in different formats using a variety of digital tools and environments.

Ability to Create Multimedia Content in Different Formats

Regarding the ability to create multimedia content in different formats using various digital tools and environments (Figure 4.8, see Appendix 5):

- **62.2%** of respondents indicated that they can create simple digital content (e.g., text, tables, images, and audio files) in at least one format using digital tools, corresponding to the **basic user** level;
- **33.3%** indicated that they can create complex digital content in different formats (e.g., text, tables, images, and audio files) and use tools for creating web pages or blogs, corresponding to the **independent user** level;
- **4.5%** indicated that they can produce complex multimedia content in different formats using a variety of digital tools and environments and can create a website using a programming language, corresponding to the **professional user** level.

Ability to Use Digital Content Formatting and Editing Functions

Regarding the ability to use digital content formatting and editing functions (Figure 4.9, see Appendix 5):

- **30.2%** of respondents indicated that they can perform basic editing of content created by other users (e.g., adding and deleting elements), corresponding to the **basic user** level;
- **62.4%** indicated that they can apply basic formatting (e.g., insert links, charts, and tables) to content created by themselves or other users, corresponding to the **independent user** level;

- **7.4%** indicated that they can use advanced formatting functions in various tools (e.g., mail merge, combining documents in different formats, advanced formulas, and macros), corresponding to the **professional user** level.

Knowledge of Rules for Using Content in Relation to Copyright Protection

Regarding knowledge of the rules for using content in accordance with copyright protection (Figure 4.10, see Appendix 5):

- **47.4%** of respondents indicated that they know that content may be protected by copyright, corresponding to the **basic user** level;
- **39.4%** indicated that they know how to cite and use copyright-protected content, corresponding to the **independent user** level;
- **13.2%** indicated that they know how and when licences and copyright provisions should be applied, corresponding to the **professional user** level.

Knowledge of Programming Fundamentals and Ability to Use Programming Languages

Regarding knowledge of programming fundamentals and the ability to use programming languages to create digital content (Figure 4.11, see Appendix 5):

- **74.9%** of respondents indicated that they can modify simple software functions by changing default settings, corresponding to the **basic user** level;
- **20.1%** indicated that they know the basics and principles of one programming language, corresponding to the **independent user** level;
- **5.0%** indicated that they can use several programming languages and know how to design, create, and modify databases using a digital tool, corresponding to the **professional user** level.

Safety

The **Safety** area concerns the protection of devices and software, personal information, health, and the environment when using digital technologies.

Ability to Protect Devices and Software

Regarding the ability to protect systems of devices and software (Figure 4.12, see Appendix 5):

- **67.2%** of respondents indicated that they can perform basic steps to protect their devices (e.g., using antivirus software and passwords), corresponding to the **basic user** level;
- **21.3%** indicated that they can install security software on devices used to access the Internet (e.g., antivirus software and a firewall), corresponding to the **independent user** level;
- **11.4%** indicated that they frequently check the security configuration and systems of devices and/or software they regularly use to access the Internet, corresponding to the **professional user** level.

Ability to Protect Personal Information

Regarding the ability to protect personal information on digital devices (Figure 4.13, see Appendix 5):

- **46.2%** of respondents indicated that they know that account credentials (username and password) can be stolen and that they should not disclose personal information online, corresponding to the **basic user** level;
- **39.3%** indicated that they use different passwords to access equipment, devices, and digital services and change them periodically, corresponding to the **independent user** level;
- **14.5%** indicated that they know how to respond if their computer is infected with a virus, can configure or modify antivirus software, and can configure the security of their digital devices, corresponding to the **professional user** level.

Ability to Use ICT Safely for Personal Health

Regarding the ability to use ICT safely for one's own health (Figure 4.14, see Appendix 5):

- **21.7%** of respondents indicated that they know that excessive use of digital technologies affects their health, corresponding to the **basic user** level;
- **32.0%** indicated that they understand the health risks associated with the use of digital technologies (e.g., the risk of psychological dependence), corresponding to the **independent user** level;
- **46.4%** indicated that they can use digital tools in a way that avoids health problems, both physical and psychological, corresponding to the **professional user** level.

Knowledge of the Impact of Digital Technologies on Everyday Life and the Environment

Regarding knowledge of the impact of digital technologies on everyday life and the environment (Figure 4.15, see Appendix 5):

- **14.0%** of respondents indicated that they take basic energy-saving measures, corresponding to the **basic user** level;
- **39.3%** indicated that they understand the positive and negative impact of technology on the environment, corresponding to the **independent user** level;
- **46.7%** indicated that they have an informed view of the impact of digital technologies on everyday life and the environment, corresponding to the **professional user** level.

Problem-Solving

The **Problem-Solving** area concerns the ability to address problems arising when using digital technologies.

Ability to Solve Problems Arising When Using Digital Technologies

Regarding the ability to solve problems arising when using digital technologies (Figure 4.16, see Appendix 5):

- **56.1%** of respondents indicated that they seek support when a technical problem occurs or when using a new application, corresponding to the **basic user** level;

- **39.8%** indicated that they can solve most of the problems that commonly arise when using digital technologies, corresponding to the **independent user** level;
- **4.1%** indicated that they can solve virtually all problems arising when using digital technologies, corresponding to the **professional user** level.

Ability to Select and Use an Appropriate Digital Tool or Service to Solve Non-Technical Problems

Regarding the ability to select and use an appropriate digital tool or service to solve non-technical problems (Figure 4.17, see Appendix 5):

- **43.7%** of respondents indicated that they know that digital tools can help them solve problems, corresponding to the **basic user** level;
- **41.9%** indicated that they can use digital technologies to solve non-technical problems, corresponding to the **independent user** level;
- **14.4%** indicated that they can freely select the appropriate tool, device, application, software, or service to solve non-technical problems, corresponding to the **professional user** level.

Ability to Select and Use an Appropriate Digital Tool to Solve Technical Problems

Regarding the ability to select and use an appropriate digital tool to solve technical problems (Figure 4.18, see Appendix 5):

- **56.4%** of respondents indicated that they can use familiar tools to solve a technological problem, corresponding to the **basic user** level;
- **38.2%** indicated that they can solve technical problems by studying the settings of software or tools, corresponding to the **independent user** level;
- **5.4%** indicated that they are aware of new technological developments and understand how new tools work, corresponding to the **professional user** level.

Awareness of the Need to Update Digital Technology Skills

Regarding awareness of the need to update skills in the field of digital technologies (Figure 4.19, see Appendix 5):

- **38.4%** of respondents indicated that they are aware of the need to regularly update their digital technology skills, corresponding to the **basic user** level;
- **40.7%** indicated that they use opportunities to fill gaps in their knowledge of information and digital technologies, corresponding to the **independent user** level;
- **20.8%** indicated that they continuously update their digital technology skills and systematically work to improve their professional level in this area, corresponding to the **professional user** level.

Conclusions Based on Teachers' Self-Assessment in the "Teacher's Digital Competence" Section

11. A positive trend can be observed in the area of **Information and Digital Literacy**. The majority of teaching staff are able to search for information at the **independent (45.6%)** and **professional (19.8%)** user levels; assess the reliability of information at the **professional (43.3%)** and **independent (24.8%)** user levels; and store information found at the **professional (41.2%)** and **independent (31.9%)** user levels. Approximately **30%** of respondents are at the basic user level and require further professional development.

12. In the area of **Communication and Collaboration**, teaching staff also demonstrate a high level of competence. The majority of respondents are able to communicate using various communication tools at the **professional (60.5%)** and **independent (20.7%)** user levels; create and manage content at the **independent (50.1%)** and **professional (21.4%)** user levels; use online services at the **independent (36.8%)** and **professional (39.1%)** user levels; and know how to use online collaboration tools at the **independent (34.9%)** and **professional (24.4%)** user levels.

Approximately **28.5%** of respondents are at the basic user level and require further professional development.

3. In the area of **Digital Content Creation**, the situation concerning the existing levels of digital competence among teaching staff is different. The majority of respondents are able to create multimedia content in various formats using a variety of digital tools and environments at the **basic (62.2%)** and **independent (33.3%)** user levels; use content formatting functions and various tools at the **independent (62.4%)** and **basic (30.2%)** user levels; understand the rules for using content in accordance with copyright protection at the **basic (47.4%)** and **independent (39.4%)** user levels; and possess programming skills at the **basic (74.9%)** and **independent (20.1%)** user levels.

On average, only approximately **10%** of respondents reach the professional user level. Problems in this area affect the formation of a culture of academic integrity in society.

4. In the area of **Safety**, the questions concerned two directions: ensuring the security of digital devices and ensuring safety related to personal health and the environment. Each of these directions demonstrates different indicators of teachers' digital competence.

The questions in the first direction aimed to determine whether teachers are able to protect their devices and software systems (**basic level — 67.2%; independent level — 21.3%**) and protect personal information on their digital devices (**basic level — 46.2%; independent level — 39.3%**).

The second direction focused on the ability to use digital tools safely for personal health (**professional level — 46.4%; independent level — 32%**) and knowledge concerning the impact of digital technologies on everyday life and the environment (**independent level — 36.8%; professional level — 45.5%**), which indicates a high level among the majority of respondents.

At the same time, according to the responses, only **12.95%** of respondents in the first direction reach the professional user level with regard to ensuring the security of their digital devices and personal data. Therefore, this issue requires greater attention.

5. In the area of **Problem-Solving**, an average of **12%** of respondents reach the professional user level, indicating certain gaps in the professional development system for teaching staff that require further improvement.

Approximately half of the respondents have the basic user level in this area, as demonstrated by the following results: ability to solve problems arising when using digital technologies (**basic level — 56.1%; independent level — 39.8%**); ability to select and use an appropriate digital tool or service to solve non-technical problems (**basic level — 43.7%; independent level — 41.9%**); ability to select and use an appropriate digital tool to solve technical problems (**basic level — 56.4%; independent**

level — 38.2%); and awareness of the need to update digital technology skills (**independent level — 40.7%; basic level — 38.4%**).

Respondents in this area require further professional development.

6. Summarising the results of the **"Teacher's Digital Competence"** section, on average, approximately **25%** of respondents are at the professional user level and more than **40%** are at the independent user level. More than half of teachers (**approximately 65%**) have a level above the basic level, while **35%** of respondents remain at the basic level and require further professional development.

Review of the Results of the 2024 Nationwide Survey

"Monitoring Teachers' Readiness and Needs Regarding the Use of Digital Tools and ICT"

In 2024, in order to monitor the dynamics of digital tool use, the **Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine**, together with the **State Scientific Institution "Institute for Modernization of the Content of Education"**, conducted the annual nationwide online survey of educators.

In 2024, **26,227 respondents** participated in the survey, compared with **42,708 in 2023** and **54,254 in 2022** (Figure 4.20, see Appendix 5).

The 2024 survey was aimed at identifying teachers' professional needs and readiness to use ICT for organising learning in a digital educational environment, identifying the most popular educational web resources and digital learning tools, and assessing teachers' level of digital competence.

Number of respondents: 26,227

Purpose: Monitoring teachers' readiness and needs regarding the use of digital tools under wartime conditions.

Survey instrument: Google Forms questionnaire.

Questionnaire sections:

I. General information about participants.
II. Organisation of learning using ICT and the digital educational environment.
III. Teachers' professional development needs concerning distance learning.
IV. Teachers' digital competence.
V. Specific features of organising learning during wartime.

The largest groups of respondents represented by the following categories: primary school teachers, Ukrainian language and literature teachers, foreign-language teachers, mathematics teachers, computer science teachers, and history teachers. Details concerning the distribution of respondents by type of professional activity are presented in Data set [41].

Popular Digital Tools

According to the survey results, teachers most frequently use the following digital tools (Figure 4.21, see Appendix 5):

- Viber — 75%
- Zoom — 65%
- LearningApps.org — 31%
- Padlet, Google Workspace for Education, Telegram — 25%
- МійКлас — 24%
- Kahoot — 19%
- Jitsi Meet — 15%
- AI — 14%

Forms of Learning

In educational institutions, **face-to-face learning** predominates (**44.9%** of responses), followed by **blended learning — 30.0%**, and **distance learning — 25.14%**.

Compared with 2023, when respondents reported a predominance of distance learning (**41.9%**), there has been a shift towards face-to-face and blended learning [41].

Ensuring the Functioning of the Digital Educational Environment

The survey showed that responsibility for maintaining the functioning of the digital educational environment in educational institutions is distributed among various specialists, including administrators, computer science teachers, deputy principals responsible for educational work, and teachers themselves.

Barriers to the Use of Digital Tools

Respondents identified the following main barriers:

- **Lack of quality Internet access — 64.7%**
- **Insufficient material and technical provision for students — 56.8%**
- **Rolling power outages — 49.1%**
- **Low level of students' self-organisation and motivation — 41.3%**
- **Lack of parental support — 30.0%**
- **Lack of time due to increased teacher workload — 25.9%**
- **Insufficient material and technical provision of educational institutions — 23.1%**

Teachers' Professional Development Needs

The survey identified the following professional development needs among teachers:

- **Improving online lesson methodology — 40.1%**
- **Creating educational videos, recording and editing lesson videos — 38.0%**
- **Learning about new online tools and services for student creativity — 34.5%**
- **Practical assistance in mastering new tools — 31.5%**
- **Courses for New Ukrainian School (NUS) teachers in lower secondary education — 27.9%**
- **Courses for New Ukrainian School (NUS) primary school teachers — 13.1%**

CONCLUSIONS

The implementation of tasks within the general secondary education system depends not only on teachers but also on other stakeholders who shape educational policy and implement it in school practice. During martial law, teachers bear the main burden of organising the educational process; therefore, they require particular attention from the state and society. Creating appropriate learning conditions for teachers and students should become a driving force for current educational changes and reforms.

Annual teacher surveys have made it possible to track the dynamics and changes in the use of digital tools, identify the continuing need for professional development, and establish the need for support from educational institutions. The experience of conducting such surveys has demonstrated the need for continuous monitoring of teachers' readiness to use ICT and has revealed a number of unresolved problems and gaps in the application of digital technologies in the educational process.

It is advisable to conduct teacher surveys at different levels — national, regional, and local — in order to obtain a comprehensive understanding of the challenges associated with the digitalisation of education. It is also important to ask teachers about their professional development needs and areas for professional growth.

Promising areas for further research may include improving tools for surveying and monitoring teachers' readiness to use ICT; incorporating aspects related to ensuring the rights and opportunities of participants in the educational process to use digital technologies; access to digital resources; sustainable development of education; compliance with academic integrity principles; safe use of ICT; and protection of personal data.

The integration of **science, technology, engineering, arts, and mathematics (STEAM)** represents a transformative approach that promotes interdisciplinary learning and prepares students for the challenges of a rapidly changing society. The effective implementation of STEAM-oriented tools depends on teachers' level of digital competence, their readiness to use innovative technologies, and their ability to create an interactive learning environment. There are different learning methods, such as project-based learning, discovery-based learning, cooperative learning, inquiry-based learning, and problem-based learning, which differ in their approaches, emphases, and degree of student autonomy and teacher involvement.

Recommendations for Improving Teachers' Readiness to Use STEAM-Oriented Tools

STEAM-oriented tools include the use of virtual and augmented reality technologies, robotics, interactive simulations, 3D modelling tools, and cloud platforms, which can significantly improve students' learning outcomes.

To determine teachers' readiness to use STEAM-oriented tools, it is necessary to assess their digital competence. A range of strategic documents, frameworks, and assessment tools can be used for this purpose, including **DigComp 2.2, DigCompEdu, ISTE Standards for Educators, "Digigram for Teachers," SELFIE for TEACHERS**, and others.

The assessment of teachers' digital competence encompasses various areas, including understanding the concepts of the digital society, professional development, the use and analysis of digital resources, and the organisation of teaching and assessment using digital technologies.

To improve the quality of teacher preparation and professional development concerning the effective use of STEAM-oriented tools, the following recommendations can be identified:

- **Include courses on STEAM education and digital technologies in teacher preparation programmes.** This will enable future teachers to become familiar with contemporary teaching methods and tools, including virtual and augmented reality, robotics, 3D modelling, and others.
- **Provide regular professional development opportunities for practising teachers** through training sessions, workshops, and courses on STEAM education and the mastery of digital tools. This will help teachers keep pace with technological developments.
- **Create or update online resources, repositories of educational materials, and interactive exercises** to support teachers' self-directed learning in the fields of STEAM education and digital technologies.
- **Encourage the exchange of experience among teachers** who already use STEAM approaches through professional communities, seminars, and web-based platforms.
- **Involve teachers in the development and piloting of STEAM-oriented educational programmes** so that they can better understand their practical application.
- **Provide schools with the necessary equipment and infrastructure**, including computers, 3D printers, robotics kits, and other resources required for implementing STEAM learning.
- **Encourage cooperation between teachers, IT specialists, and representatives of STEAM-related industries** to develop a better understanding of the practical application of technologies.
- **Conduct regular monitoring and assessment/self-assessment of teachers' digital competences** using DigComp 2.2, DigCompEdu, and other frameworks to identify gaps and professional development needs.

Thus, a comprehensive and systematic approach to teachers' professional development in STEAM education and digital technologies will enable educators to integrate these tools effectively into the educational process.

Strategies for Assessing the Effectiveness of STEAM-Oriented Teaching Methods

Several strategies can be used to assess the effectiveness of teaching methods based on the STEAM approach.

Assessment of Students' Learning Outcomes

It is important to conduct standardised tests or examinations to assess the level of students' knowledge and skills before and after the implementation of STEAM methods.

It is also necessary to analyse the quality of projects created by students within Project-Based Learning. Teachers should assess students' ability to apply interdisciplinary knowledge to solve real-world problems.

Student Surveys and Feedback

This strategy involves surveying students to determine their views on the effectiveness of STEAM methods, as well as their interest and motivation to learn.

It is important for teachers to collect students' feedback concerning problematic aspects they encounter when using digital technologies.

Observation of the Educational Process

Experts may be involved in observing how teachers use STEAM methods during lessons. Experienced colleagues can provide advice and recommendations on overcoming challenges and improving teaching methods through the use of digital tools.

It is also important to assess the level of student engagement, interaction, and collaboration within the applied methods.

Analysis of Students' Skills Development

This approach involves monitoring the development of students' **critical thinking, creativity, communication, and problem-solving skills**.

In this context, it is also advisable to assess students' ability to engage in self-directed learning and research activities.

Assessment and Self-Assessment of Teachers' Digital Competences

Particular attention should be paid to the assessment and self-assessment of teachers' digital competences. For this purpose, the use of international frameworks and national standards, in particular **DigComp 2.2** and **DigCompEdu**, is recommended.

This process should be conducted regularly and at different levels: **local, regional, and national**. Such assessment is particularly important during teachers' professional development.

It is also necessary to analyse teachers' progress and professional development needs in order to ensure the effective application of STEAM methods.

In 2024, the **Ukrainian Institute for Education Development (UIED)** developed questionnaires for the self-assessment of teachers' professional competences, including information and digital competence. The proposed approach uses a **five-point scale** for such self-assessment.

Involvement of External Experts and Partners

This component involves representatives of STEAM-related industries in assessing students' preparation for future careers.

It would be advisable to plan research into feedback from universities and employers concerning the readiness of graduates who have completed STEAM-based education.

Thus, combining **quantitative and qualitative assessment methods**, involving all stakeholders, and conducting regular monitoring will make it possible to objectively assess the effectiveness of STEAM-oriented teaching methods used by teachers in their professional practice.

Teachers' Self-Assessment and Their Readiness to Use Digital Tools

As noted above, the self-assessment process is important for teachers because it enables them to identify their own gaps, problems, needs, and progress in the use of digital technologies.

This process must be supported by relevant institutions and based on recognised standards and requirements for teachers' professional qualifications. These requirements should be regularly updated in accordance with technological development and the emergence of new standards and requirements for the teaching profession.

Therefore, the need for continuous monitoring of teachers' readiness to use **ICT** at different levels — national, regional, and local — should be systematically organised and supported by educational institutions.

This will contribute to obtaining a comprehensive understanding of teachers' readiness to use ICT, developing plans and strategies for the digitalisation of educational processes, and creating conditions for teachers' professional growth.

Surveys should be conducted on a **voluntary and confidential basis** and should address teachers who find themselves in different life circumstances, including those who have become refugees, internally displaced persons, or have lost their employment.

There is a need for continuous improvement of tools for surveying and monitoring teachers' readiness to use ICT. Such tools should incorporate aspects including:

- the state of ensuring teachers' and students' rights and opportunities to access quality educational services;
- access to digital technologies;
- access to digital resources;
- compliance with gender equality and inclusion principles;
- academic integrity when using the Internet and obtained data;
- safe use of ICT;
- protection of children's and adults' personal data within the educational process.

Teacher and student support during wartime is particularly important. All these issues may become areas for teachers' professional development under contemporary conditions and contribute to overcoming **educational losses during wartime**.

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APPENDICES

Appendix 1

Assessment and Analytical Competence

Extract from the Order of the Ministry of Education and Science of Ukraine, Kyiv, August 29, 2024, No. 1225

On Approval of the Professional Standard "Teacher of a General Secondary Education Institution"

Source: Ministry of Education and Science of Ukraine.

Appendix 2

Comparison of the Percentage of Teachers' Use of Online Tools in 2021, 2022, and 2023 During Distance and Blended Learning

Digital tools	**% of use in January–February 2021**	**% of use in January–February 2022**	**% of use in February–March 2023**
Viber	83	78.4	77.7
Zoom	58.7	65.4	63.8
Google Apps for Education	15.1	20.2	53.1
Electronic diary	11.7	15.4	34.1
LearningApps.org	n.d.*	n.d.	26.7
Telegram	13.8	13.3	26.0
Educational institution website	58.7	23.5	24.7
МійКлас	20.7	19.5	22.1
Padlet	18.8	11.0	16.8
Kahoot	n.d.	n.d.	11.9
Skype	14.0	8.3	6.9
Microsoft Teams	4.0	4.7	4.9
WhatsApp	4.0	3.3	4.8
Jitsi Meet	9.5	13.1	4.4
Moodle	4.0	3.2	3.8
Mentimeter	n.d.	n.d.	3.8
TikTok	4.0	1.4	2.9

Note: n.d. — no data available.

A comparison of respondents' answers for 2021, 2022, and 2023 shows that **Viber, Zoom, Google Apps for Education, electronic diaries, LearningApps.org, Telegram, and educational institution websites** remained among the most frequently used tools by teachers. In 2023, their overall usage ranged from **77.7% to 24.7%**.

Sources:

[11] O. V. Ovcharuk and I. V. Ivaniuk, *Results of the Online Survey "Teachers' Readiness and Needs Regarding the Use of Digital Tools and ICT under Quarantine Conditions: 2021": Analytical Report*, 2021, 55 p.

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Appendix 3

Stages of Implementing the Teacher Digital Competence Self-Assessment Tool

Source: Authors' own research

STAGES OF IMPLEMENTING THE SELF-ASSESSMENT TOOL

Stage I — Development, 2020

↓

Stage II — Improvement, 2021

↓

Stage III — Implementation, 2022, 2023, 2024

Appendix 4

Information and Digital Competence

Extract from the Order of the Ministry of Education and Science of Ukraine, Kyiv, August 29, 2024, No. 1225

On Approval of the Professional Standard "Teacher of a General Secondary Education Institution"

Source: Ministry of Education and Science of Ukraine.

Information and Digital Competence

Labour functions	Competences	Knowledge	Skills and abilities	Communication	Responsibility and autonomy
	Information and digital competence				

33.1. Ability to Navigate the Information Environment, Search for and Critically Evaluate Information, and Use It in Professional Activities

Knowledge

A3.1.31. Functional literacy in the use of digital devices, their basic software, online services, including financial services, and the Internet.

A3.1.32. Rules for critically evaluating information and criteria for media literacy and digital financial literacy.

A3.1.33. Digital environments, professional online communities, and electronic (digital) resources for continuous professional development throughout the lifespan.

A3.1.34. Legislative requirements concerning academic integrity and the use of copyrighted works; netiquette in professional activities.

A3.1.35. Safety rules in the digital environment and the consequences of the impact of digital information on individuals.

Skills and abilities

A3.1.U1. Use digital devices and their basic software; work with operating systems, online services, files, and the Internet.

A3.1.U2. Critically evaluate the accuracy and reliability of information sources, as well as the impact of information on the consciousness and development of students and on decision-making.

A3.1.U3. Use open electronic (digital) educational resources for professional development and the exchange of teaching experience; create and maintain one's own e-portfolio.

Communication

A3.1.K1. Interact with participants in the educational process to create communities for sharing experience in the use of digital technologies.

Responsibility and autonomy

A3.1.V1. Recognise the importance of digital hygiene and initiate and conduct activities promoting compliance with digital hygiene requirements among participants in the educational process.

A3.1.V2. Avoid dangers in the information environment; ensure the protection and preservation of personal data.

33.3. Ability to Use Digital Technologies in the Educational Process

Knowledge

A3.3.31. Approaches to organising the educational process using digital technologies, including distance learning, and conditions for organising digital workplaces.

A3.3.32. Digital technologies and electronic (digital) educational resources for teaching students subjects and integrated courses, assessing and monitoring learning outcomes, organising students' self-control, and tracking their learning progress.

Skills and abilities

A3.3.U1. Use a secure electronic (digital) educational environment to organise and manage the educational process, organise group interaction and feedback, and collaboratively create electronic (digital) educational resources.

A3.3.U2. Analyse and interpret information in an electronic (digital) environment concerning students' activity and effectiveness of learning activities; implement assessment strategies using digital services; select digital assessment tools and critically analyse the appropriateness of their use.

Communication

A3.3.K1. Communicate with participants in the educational process using various electronic (digital) tools and services.

Responsibility and autonomy

A3.3.V1. Provide assistance and support to other participants in the educational process in mastering digital technologies.

A3.3.V2. Use secure digital resources to organise students' learning.

Work Objects and Tools

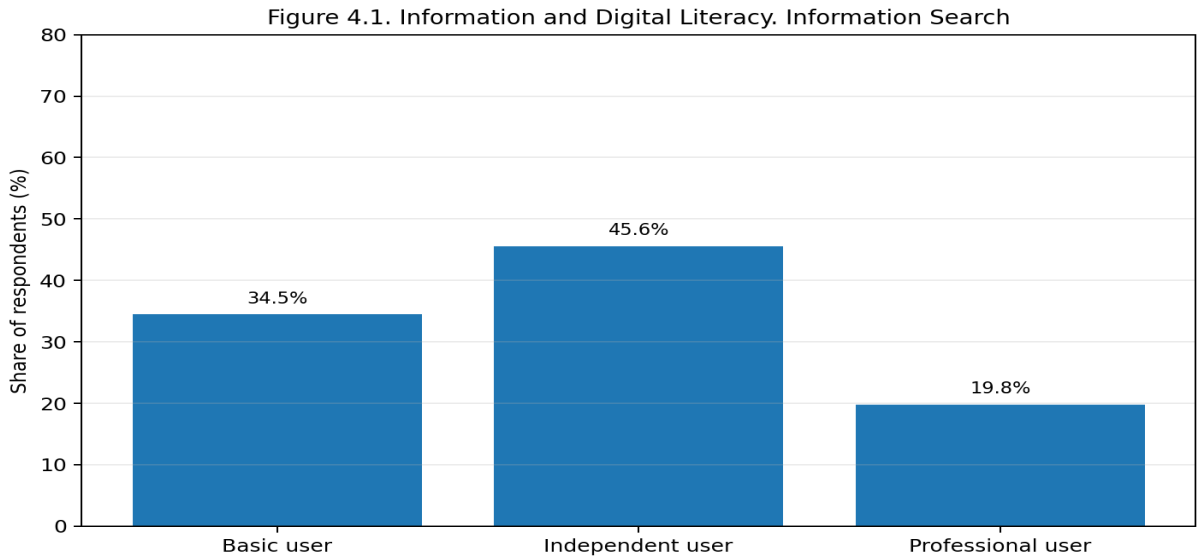
Furniture, stationery, personal computer (laptop), projector, printer, scanner, and other office equipment; electronic educational platforms; electronic (digital) educational resources; legislative requirements governing the organisation of the educational process; state standards; educational programmes; model curricula; curricula; textbooks; manuals; recommendations; visual aids; pedagogical software tools, etc.

APPENDIX 5

FIGURES AND CHARTS ILLUSTRATING THE RESULTS OF THE NATIONWIDE TEACHER SURVEY

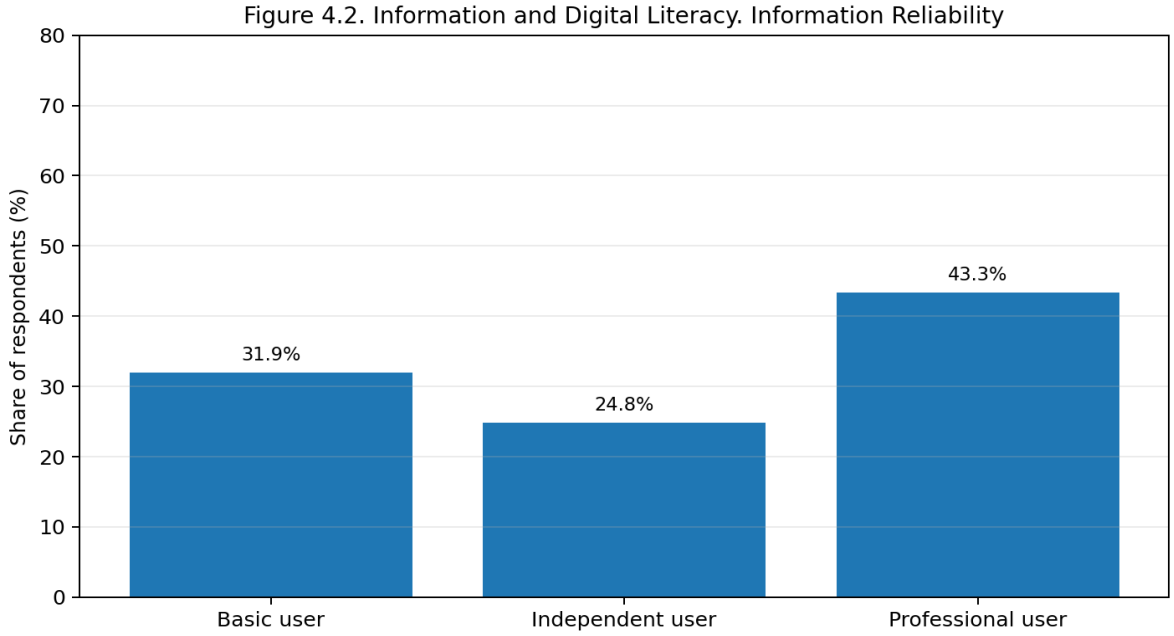
This appendix contains English-language versions of the charts illustrating the results of the teachers' digital competence self-assessment and the nationwide teacher survey. The numerical values are retained from the source document. The Data set [41].

Figure 4.1. Information and Digital Literacy. Information Search



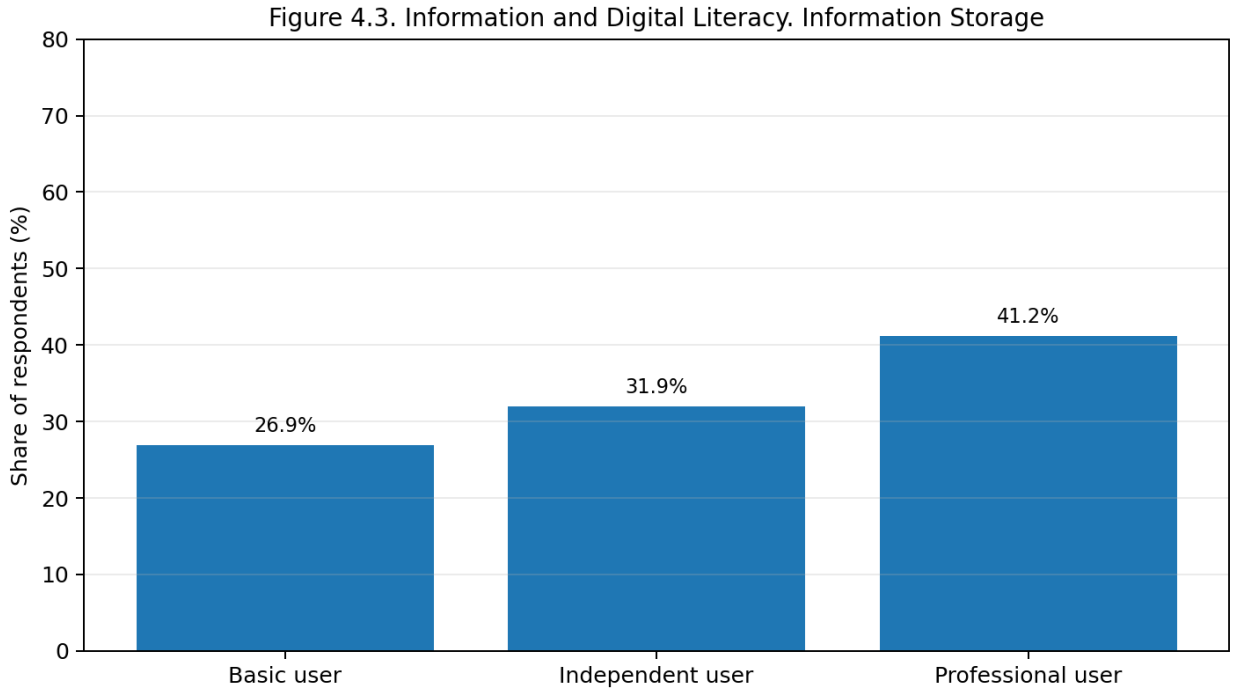
Source: Authors' data.

Figure 4.2. Information and Digital Literacy. Information Reliability



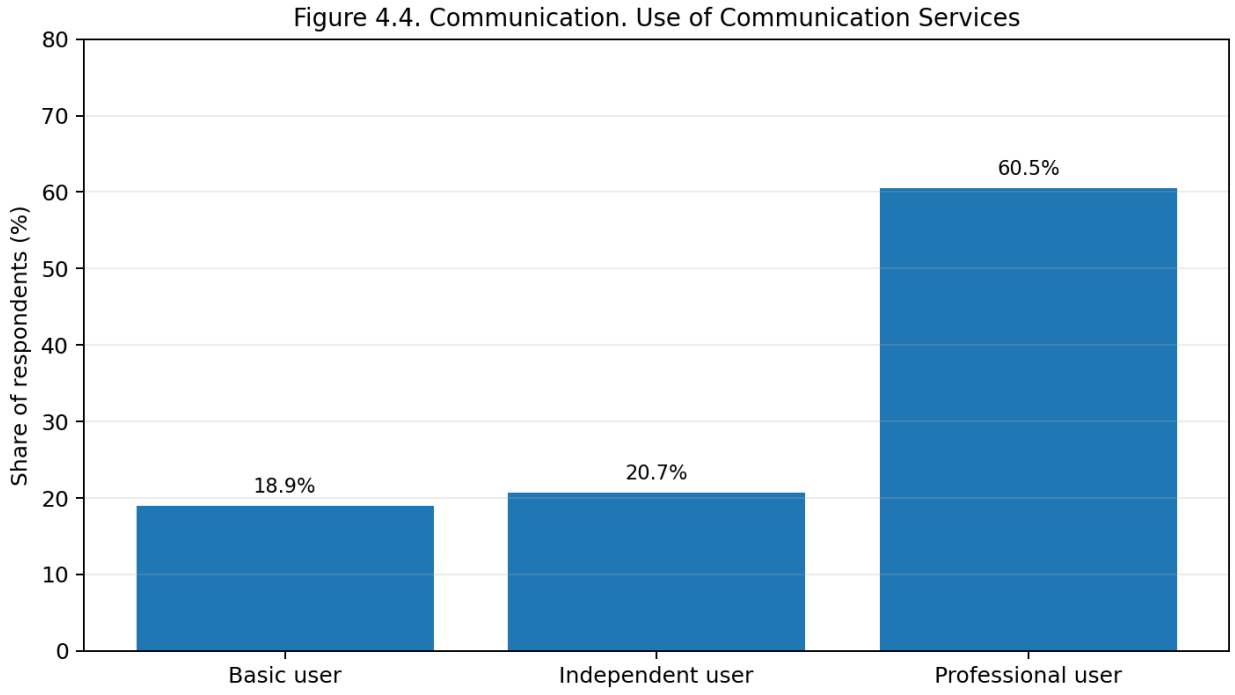
Source: Authors' data.

Figure 4.3. Information and Digital Literacy. Information Storage



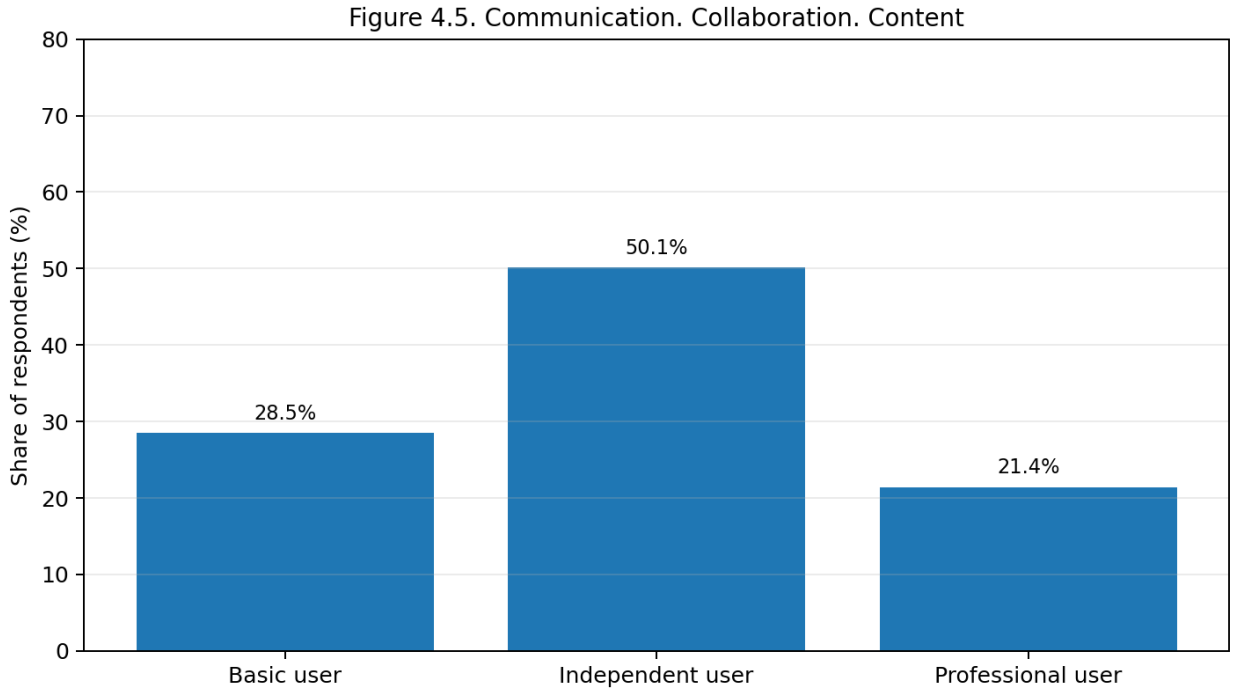
Source: Authors' data.

Figure 4.4. Communication. Use of Communication Services



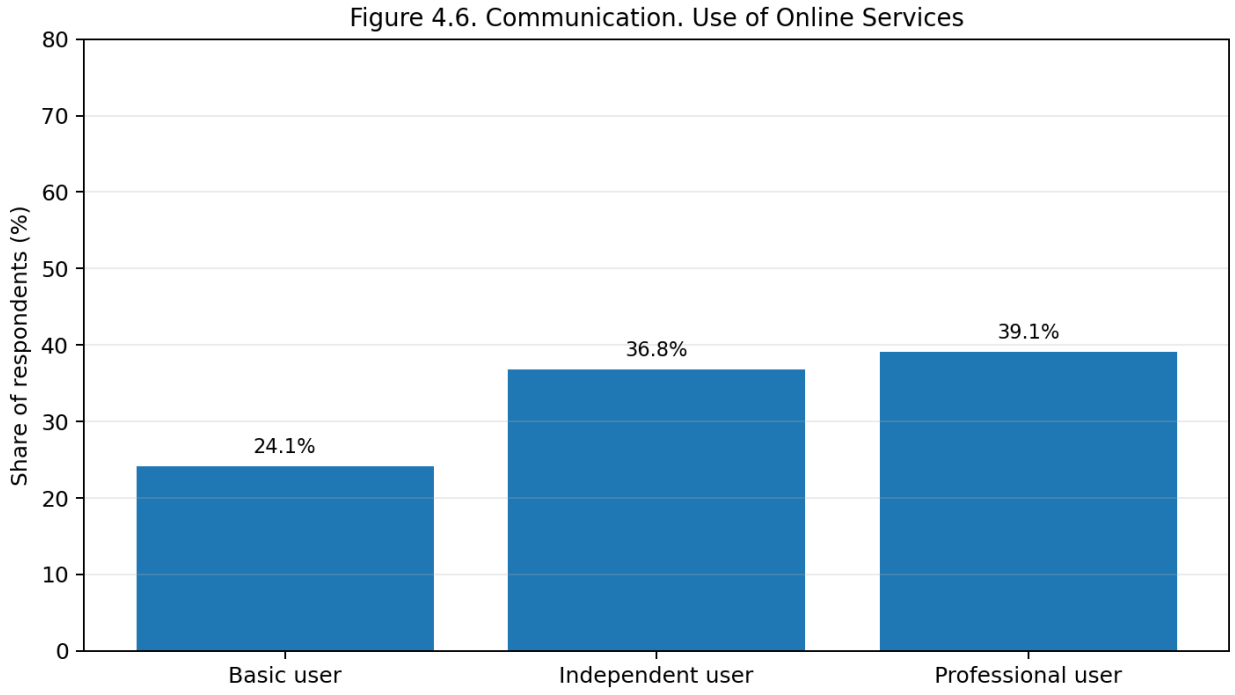
Source: Authors' data.

Figure 4.5. Communication. Collaboration. Content



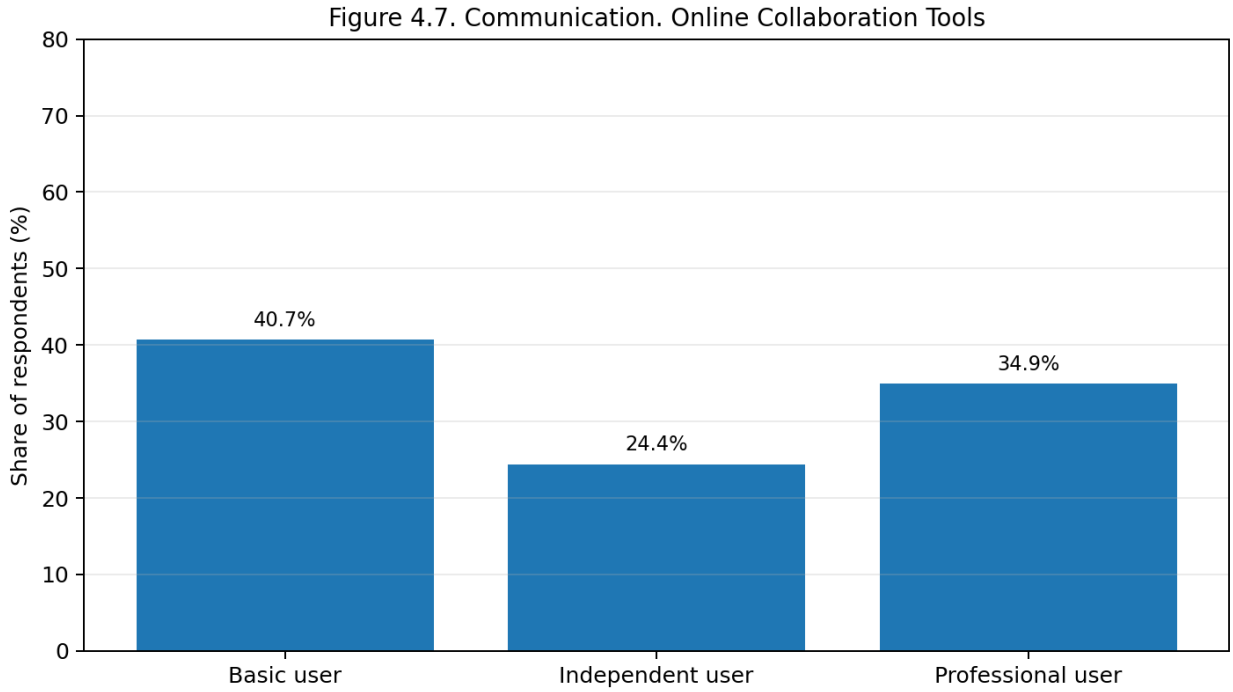
Source: Authors' data.

Figure 4.6. Communication. Use of Online Services



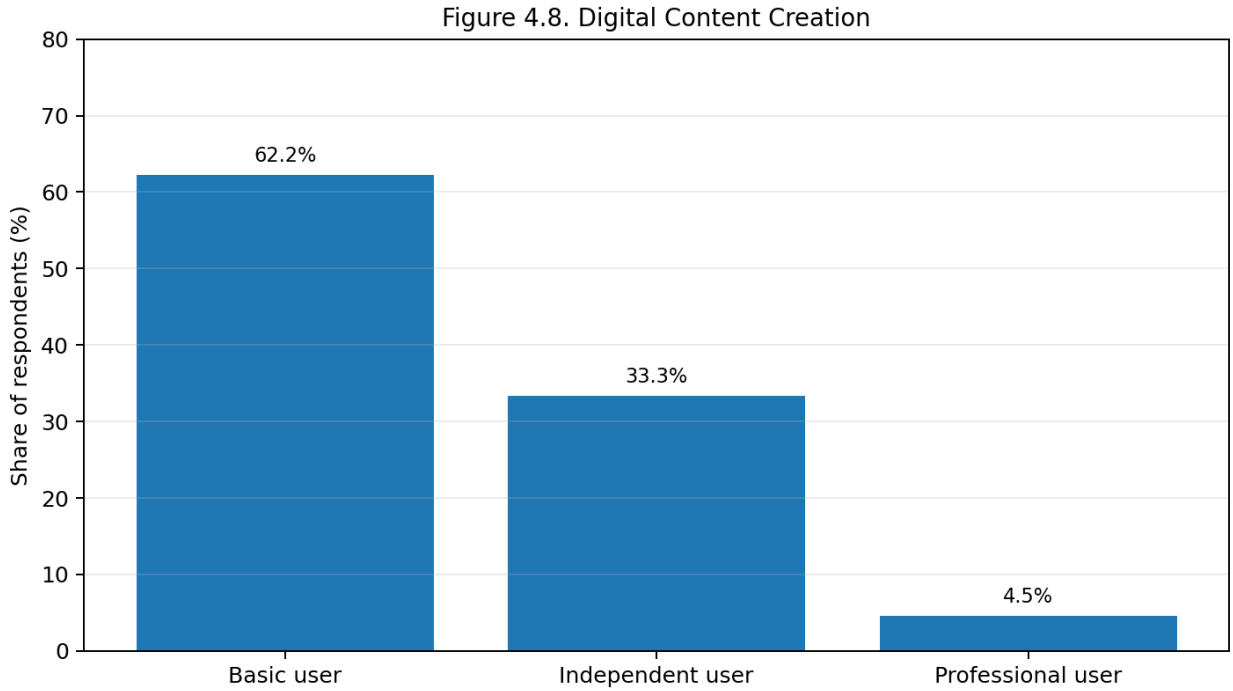
Source: Authors' data.

Figure 4.7. Communication. Online Collaboration Tools



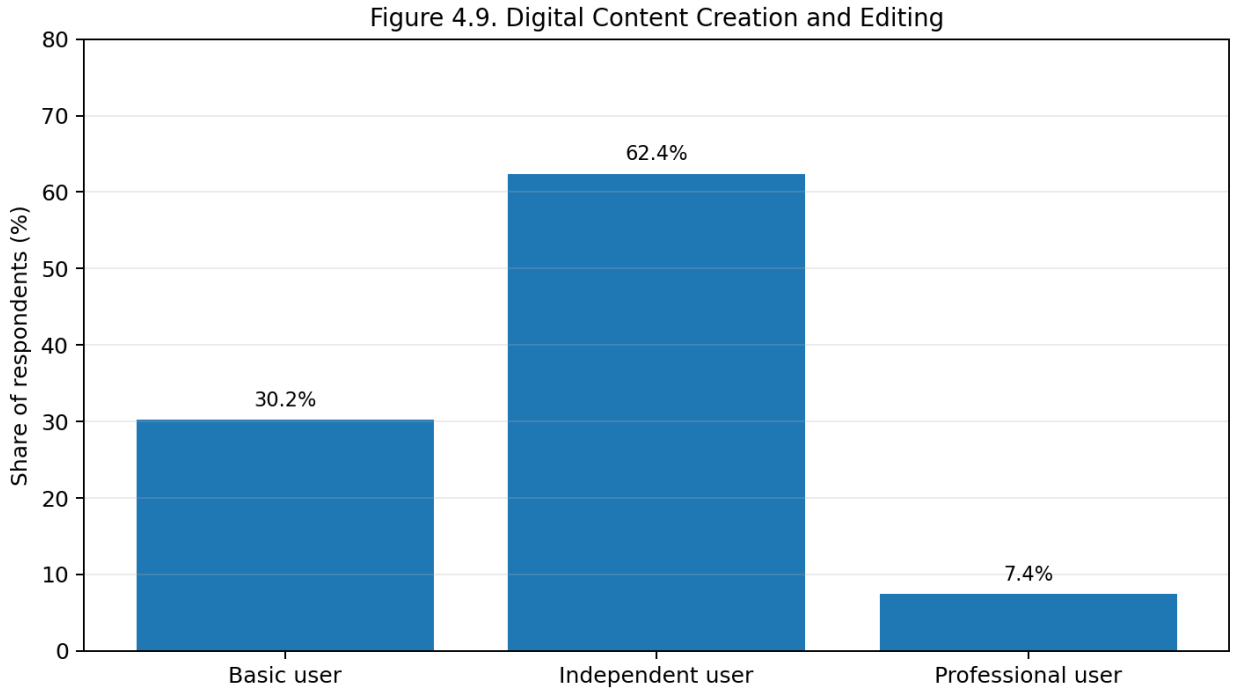
Source: Authors' data.

Figure 4.8. Digital Content Creation



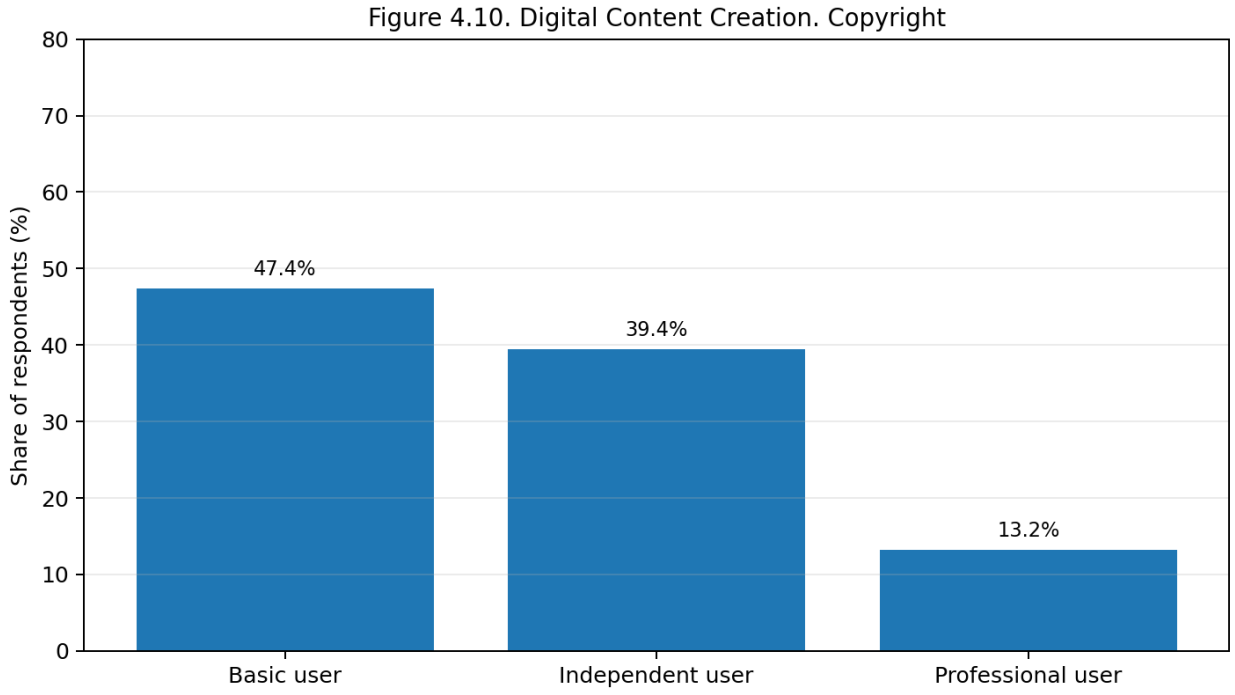
Source: Authors' data.

Figure 4.9. Digital Content Creation and Editing



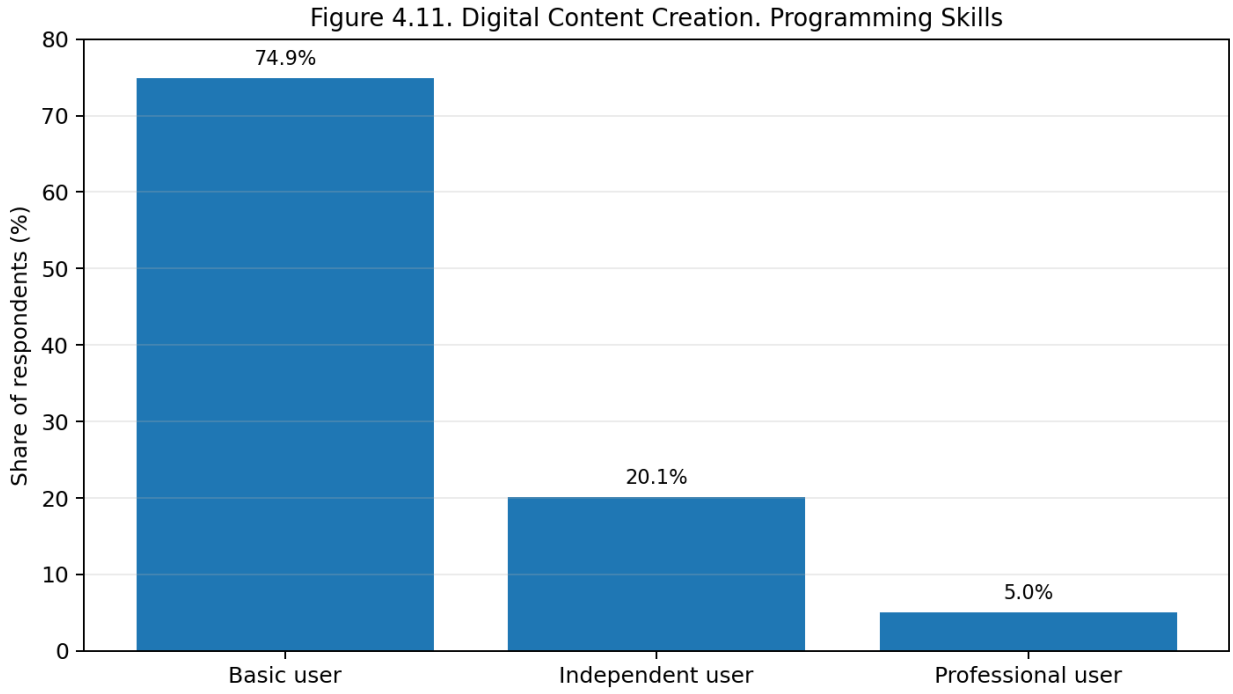
Source: Authors' data.

Figure 4.10. Digital Content Creation. Copyright



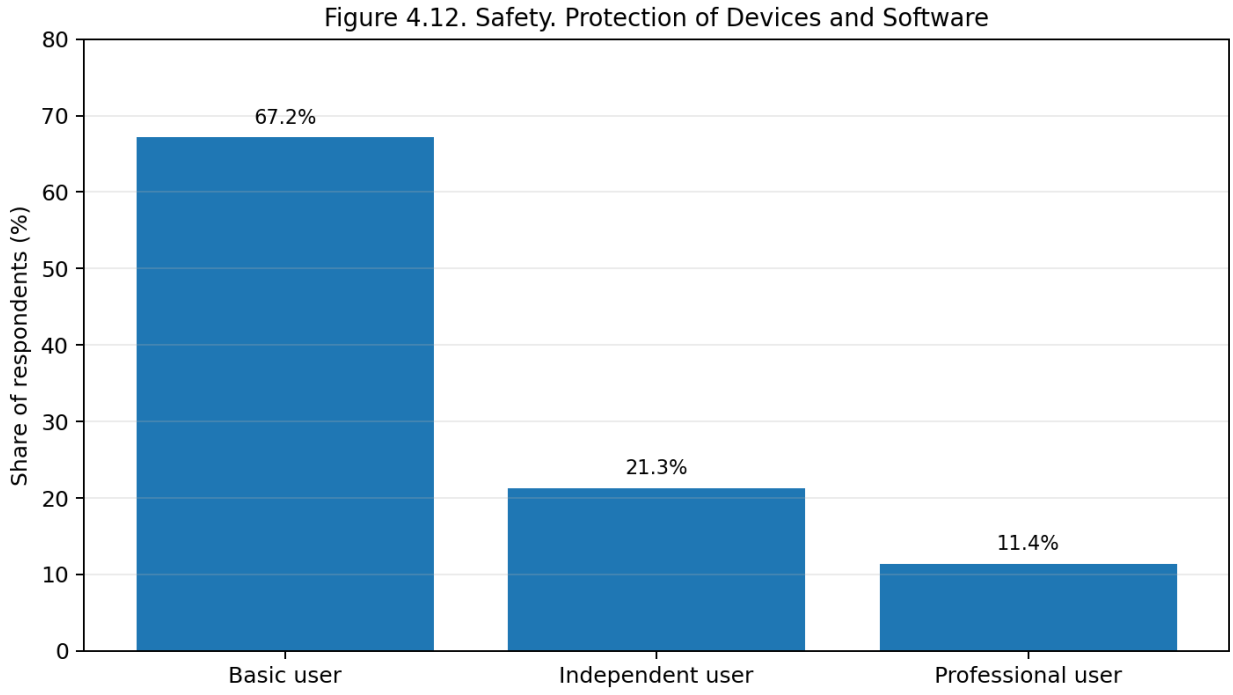
Source: Authors' data.

Figure 4.11. Digital Content Creation. Programming Skills



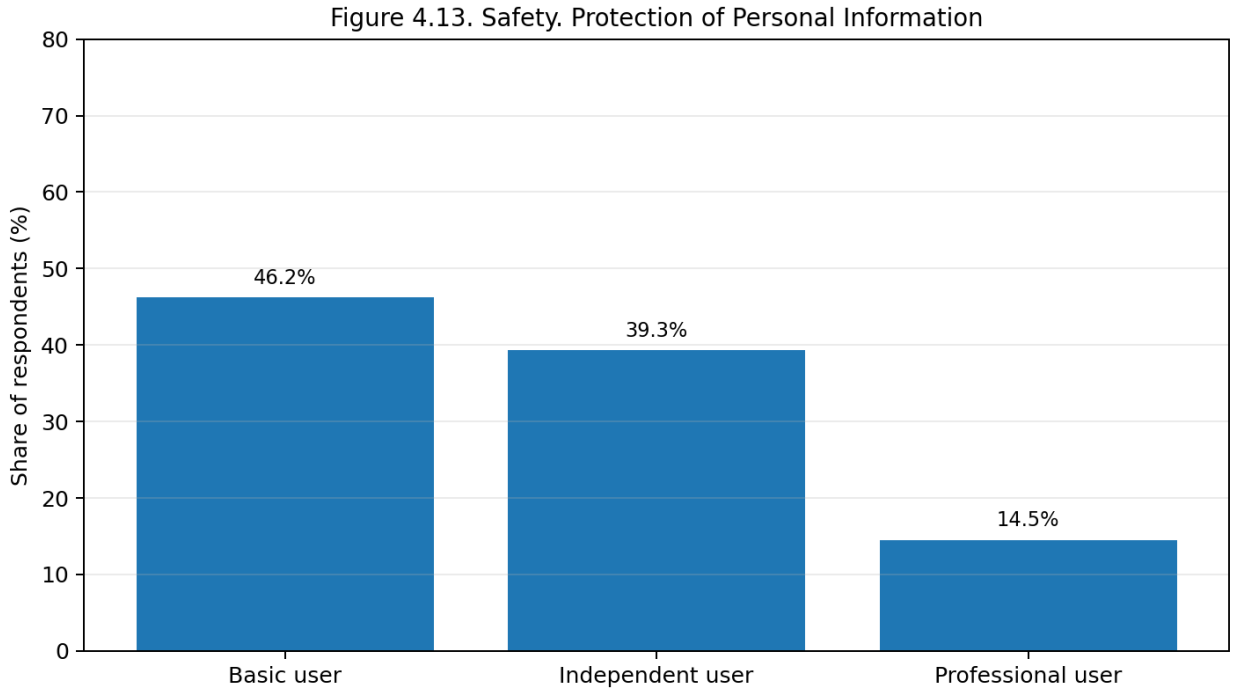
Source: Authors' data.

Figure 4.12. Safety. Protection of Devices and Software



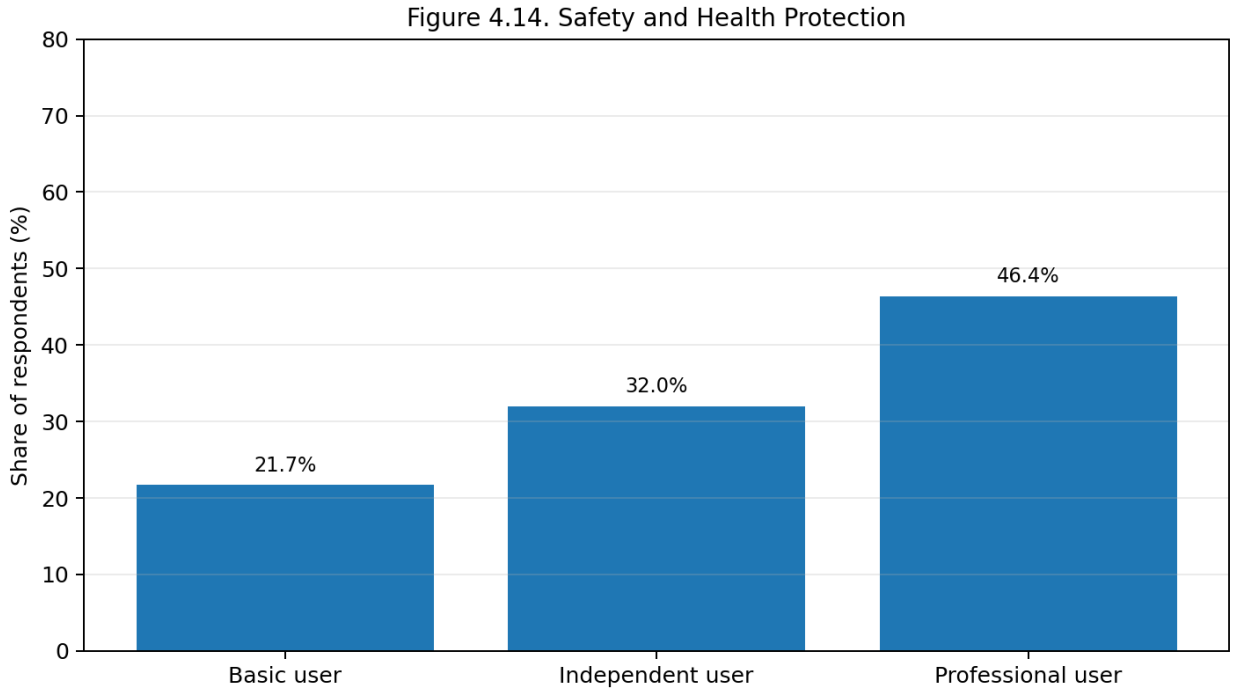
Source: Authors' data.

Figure 4.13. Safety. Protection of Personal Information



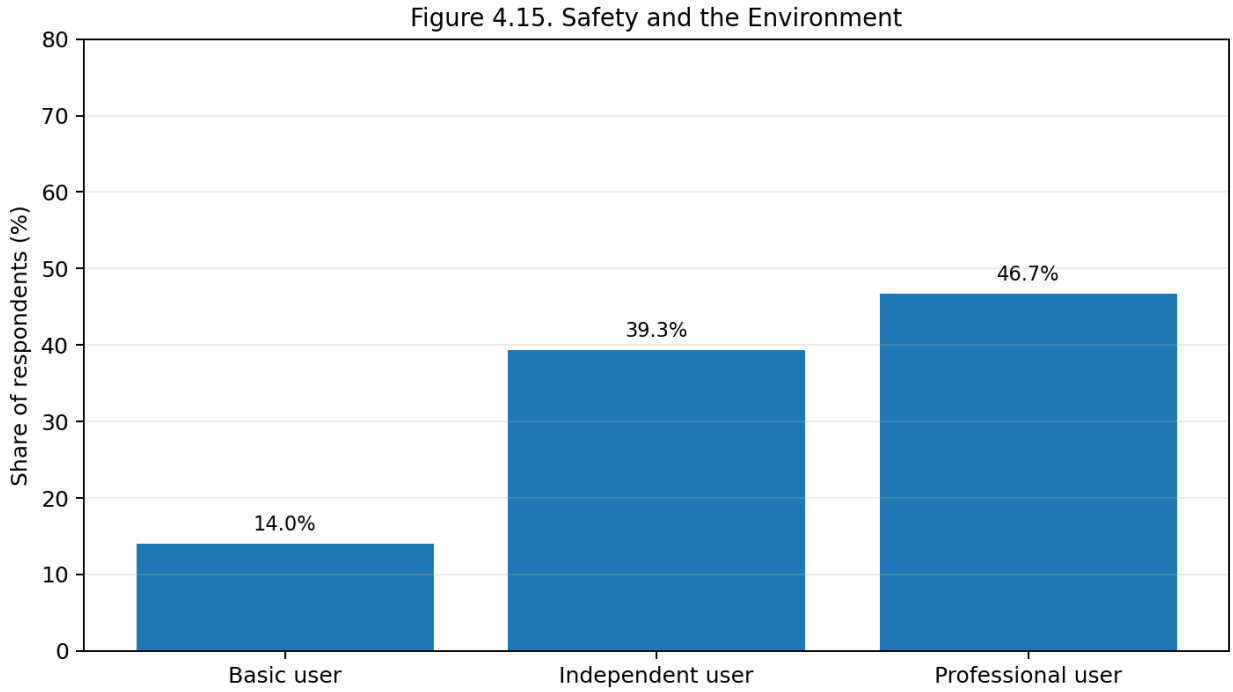
Source: Authors' data.

Figure 4.14. Safety and Health Protection



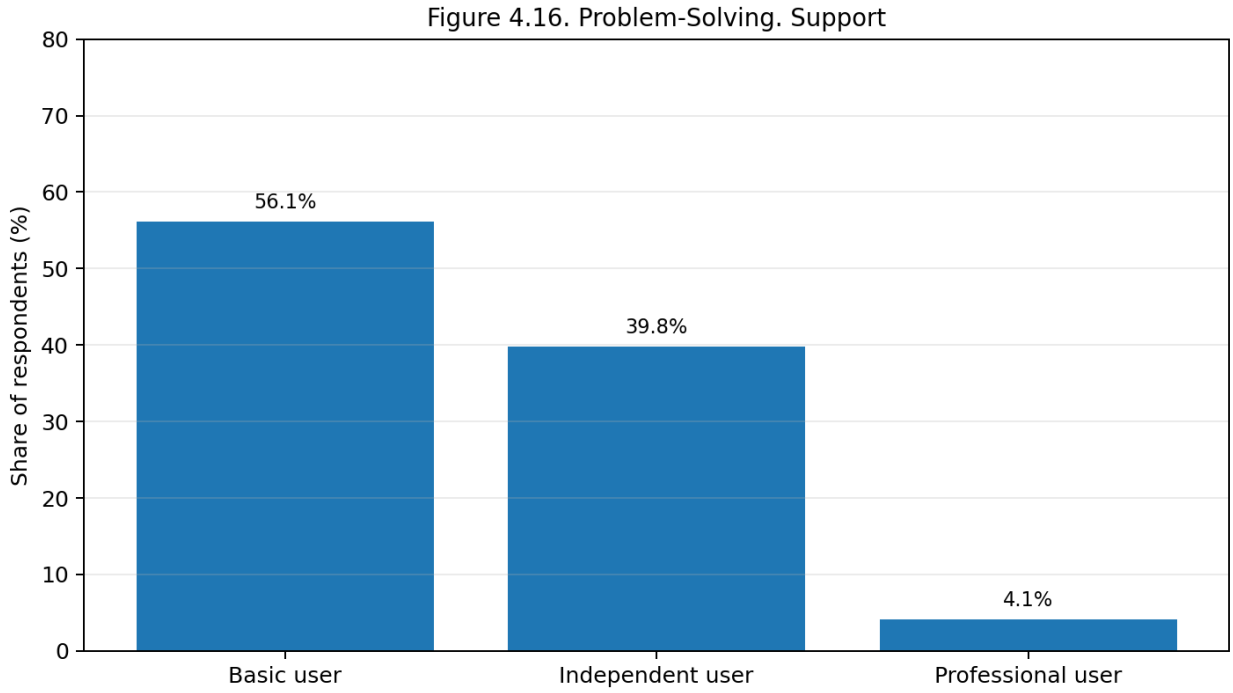
Source: Authors' data.

Figure 4.15. Safety and the Environment



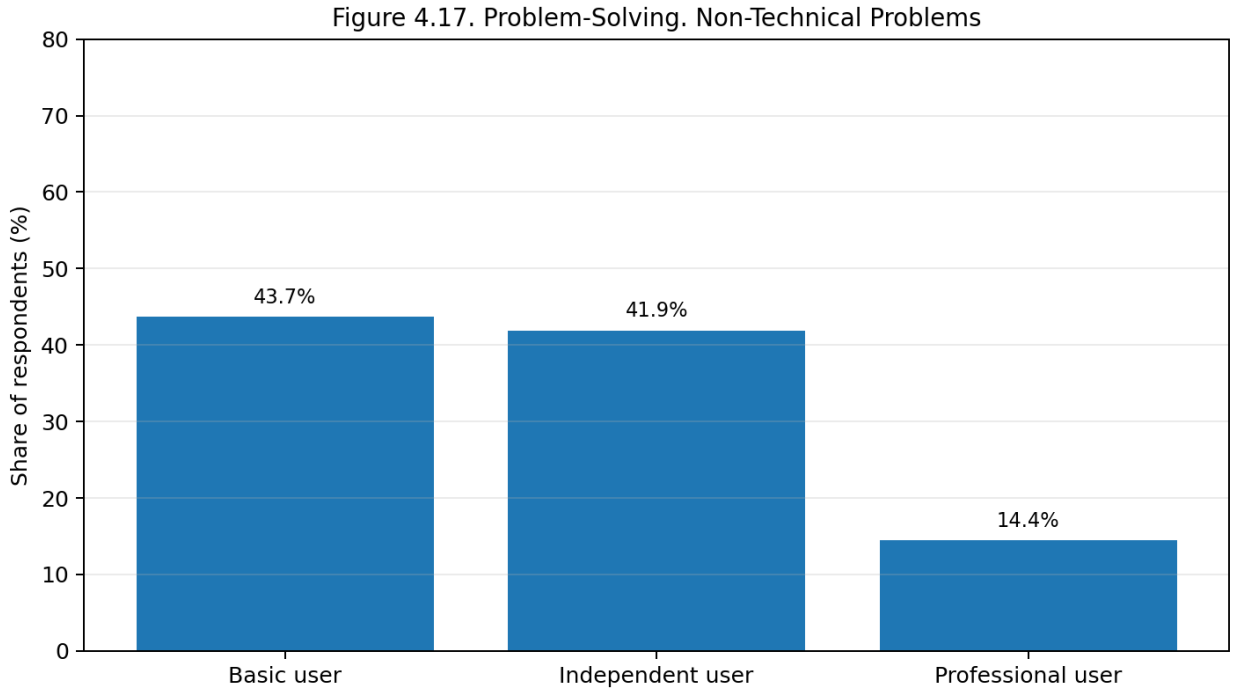
Source: Authors' data.

Figure 4.16. Problem-Solving. Support



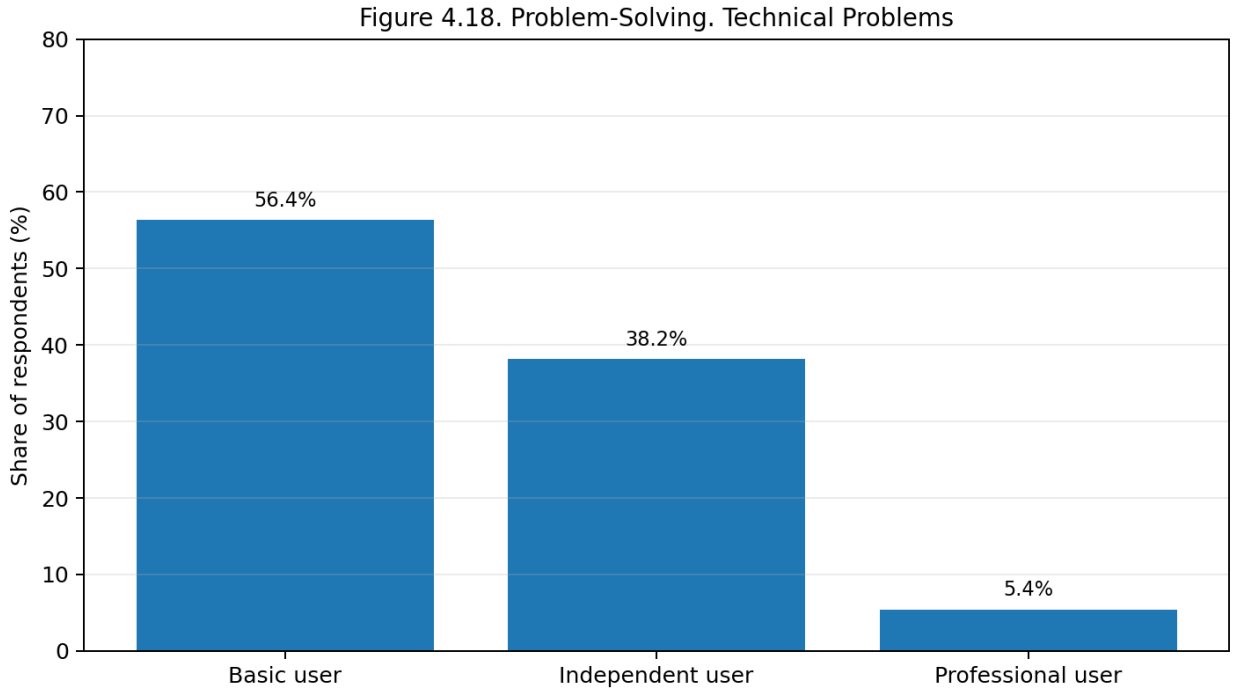
Source: Authors' data.

Figure 4.17. Problem-Solving. Non-Technical Problems



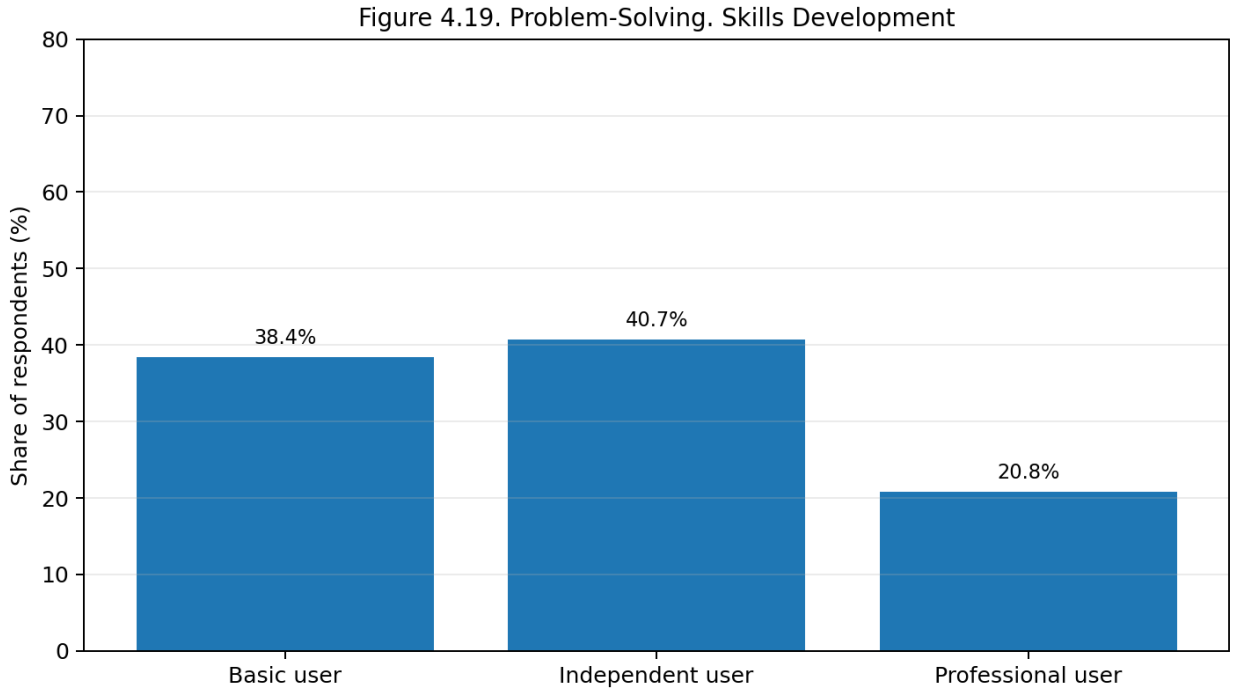
Source: Authors' data.

Figure 4.18. Problem-Solving. Technical Problems



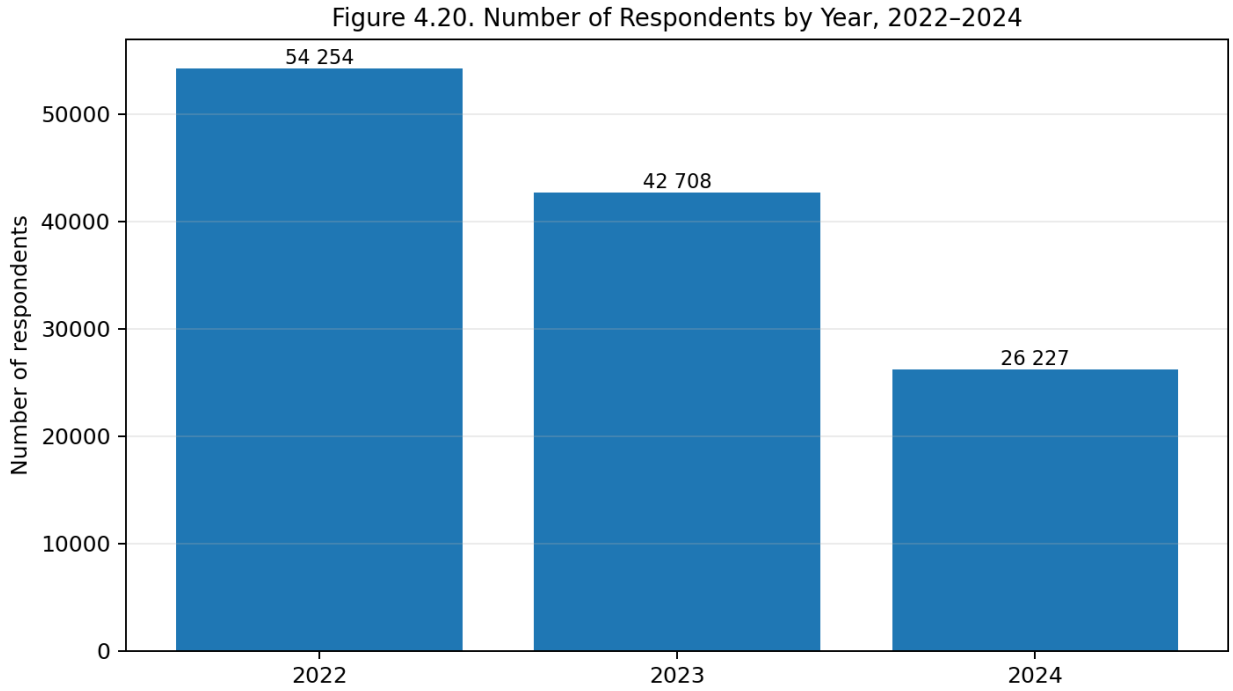
Source: Authors' data.

Figure 4.19. Problem-Solving. Skills Development



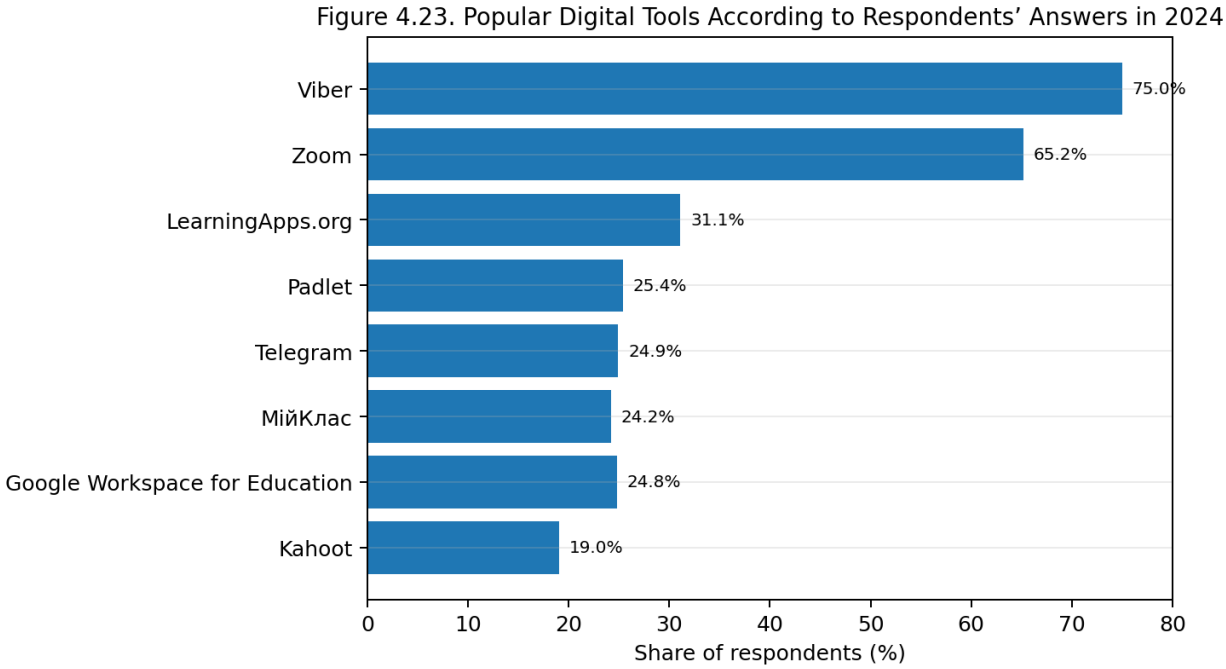
Source: Authors' data.

Figure 4.20. Number of Respondents by Year, 2022–2024



Source: Authors' data.

Figure 4.21. Popular Digital Tools According to Respondents' Answers in 2024



Source: Authors' data.

SCIENTIFIC PUBLICATION

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