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To cite this article: T H Kramarenko and V M Kramarenko 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1415** 012013

View the article online for updates and enhancements.

The use of digital technologies in education in the context of sustainable development of society

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Abstract. One of Ukraine's Sustainable Development Goals is to ensure inclusive and equitable quality education and to promote lifelong learning opportunities for all citizens. Therefore, it is important to develop the professional skills and pedagogical competence of teachers to prepare future generations to achieve the Sustainable Development Goals through education. In particular, through the digitalization of education. The purpose of this article is to highlight the state of use of digital technologies and innovative approaches by teachers of Kryvyi Rih district in the context of blended learning in the context of sustainable development of society. The problems of development and use of video materials and interactive tools, virtual simulations, workshops and laboratories in teaching are considered. The issue of using game technologies for learning is highlighted. The use of platforms for collaboration and exchange of views between students and the use of e-learning systems is analysed.

1. Introduction

Today, digitalization is seen as an important driver of socio-economic development [1, 2]. The educational system, determining the social profile of the country's future, plays an important role in society. In particular, as a factor in eliminating inequality among citizens. One of the Sustainable Development Goals of Ukraine, as stated in the Presidential Decree [3], is to ensure inclusive and equitable quality education and to promote lifelong learning opportunities for all citizens [4].

Preparing generations to meet the Sustainable Development Goals is a major challenge. The use of cloud technologies [5–11], augmented reality [12–24], the development of tools for collecting and analyzing Big Data, 3D printing, etc. are changing both various sectors of the economy and society as a whole. This requires the training of a teacher who is motivated and able to participate in the creation of a new school based on the widespread use of digital technologies, cooperation and mutual understanding between all participants in the educational process.

Therefore, a modern teacher should be focused on professional and personal growth throughout his or her teaching career. Education for sustainable development is lifelong and includes all levels and categories of education and training. This includes formal education, including secondary and higher education, as well as retraining and re-qualification. In non-formal education, self-education, including for people of retirement age, is the mainstay.

In the context of the unstable security situation in Ukraine, a significant number of higher and secondary education institutions have been forced to switch to online or blended learning. This has become a serious challenge for many participants in the educational process. Many studies show significant educational losses caused by the inability to fully conduct classes. The

ICSF-2024

IOP Publishing

IOP Conf. Series: Earth and Environmental Science **1415** (2024) 012013

doi:10.1088/1755-1315/1415/1/012013

difficulties of transitioning to online learning are especially noted by future teachers who are undergoing internships in educational institutions. This has revealed serious shortcomings in the pedagogical integration of ICTs, raising awareness of the need to develop digital competencies for each of the participants in the educational process.

The appropriate use of digital technologies in education will help make the learning process effective, accessible and motivating for students. It will help to ensure that the Sustainable Development Goals are met.

2. Theoretical background

Sustainable development is development that meets the requirements of the present without compromising the ability of future generations to meet their own needs. Fedulova [25] characterizes the global trends in the development and implementation of digital technologies to achieve the goals of sustainable development in the context of digitalization of the economy and society, and identifies key tasks in this area for Ukrainian science and public policy. The author identifies the following trends: 1) the complex impact of Industry 4.0 technologies on the achievement of the Sustainable Development Goals; 2) digital technologies as a driver of a new stage of sustainable development and opening of new markets, which concerns the activities of large corporations; 3) the intensification of international organizations in the transfer of digitalization policy.

García-Hernández et al. [26] note that adequate use of ICT is necessary to promote educational practices that contribute to sustainable development. The systematization of research in this area is seen as an opportunity to contribute to existing theories and practices related to the use of ICT and the development of the Sustainable Development Goals. According to the challenges, the authors identify innovative proposals that can be used to address sustainable development issues. In particular, the development of sustainable technological tools can be ensured through the creation of virtual tools or courses for quality education, and e-learning strategies need to be improved to ensure equitable and quality education.

Jeong and González-Gómez [27] consider mathematics education as a cornerstone for sustainable development. However, the problems of sustainable development are related to the typical issues of ecology and economy in the educational sphere. The authors note that, under the influence of modern ICT, changes in pedagogy lead to significant contradictions in teaching/learning mathematics. This study attempts to classify and investigate the criteria of mathematics education using the method of multi-criteria decision analysis/testing laboratory and fuzzy decision evaluation in the context of a flipped e-learning system.

Hilty and Huber [28] investigate the motivation of ICT students to study specific topics in the field of sustainable development.

Al-Rahmi et al. [29] highlight the problems of usng ICT for sustainable development of education. The authors analyze the factors that influence the intention to use ICT in education and their satisfaction with this use.

Serhiienko [30] defines that the tasks of education for sustainable development are reorientation of existing curricula towards social, economic, environmental knowledge and perspectives; formation of experience and values necessary for sustainable development; training of personnel in the interests of transition to sustainable development and further development of education for sustainable development.

The problems of digitalization of education are reflected in the work by Dziabenko et al. [31]. Among the tools of digital technologies, the authors distinguish tools for communication, collaboration, content creation, work organization, search, video and audio, and mobile applications. Educational trends include, in particular, practice-oriented learning, competence development, personalization, STEAM education, and entrepreneurship development. The authors of the study note that the most popular pedagogical technologies are research-based

ICSF-2024

IOP Publishing

IOP Conf. Series: Earth and Environmental Science **1415** (2024) 012013

doi:10.1088/1755-1315/1415/1/012013

learning through the use of ICT, blended learning, maker education, formative assessment, integrated learning and inclusive education technologies.

Kartashova et al. highlight the technology of digital twins for blended learning in educational institutions [32]. This will provide free access to educational resources and networking for students.

Kuzminska et al. [33] study the problems of forming digital competence of students and teachers in Ukraine. In particular, measurement, analysis, and development prospects.

Mintii [34] notes that today, blended learning is characterized by studies that consider practical experience of implementation. The leading approaches to the organization of blended learning are highlighted: by the method of combination, by ICT tools, by appropriate pedagogical technologies.

The studies discussed above actualize the issue of forming professional skills and pedagogical competence of teachers to ensure the Sustainable Development Goals of society through education. There is a lack of research that would systematize innovative proposals that contribute to solving the problems of sustainable development of education. This is especially true for inclusive education and education in an unstable security situation.

3. Methodology

During 2021-2023, we monitored the use of digital technologies by mathematics and computer science teachers during their internships in educational institutions of the Kryvyi Rih district in a blended learning environment. We also conducted a survey on the use of online tools by math teachers during their professional development courses. Almost ninety teachers answered the questionnaire about the use of digital technologies during this period.

As part of the teacher training courses, we invited experienced math teachers to share their practice of using digital technologies in blended learning. At the same time, invited guests and experts took part in discussions, answered questions from students to expand their knowledge and improve their skills in using online tools.

The purpose of this article is to highlight the state of use of digital technologies and innovative approaches by teachers of Kryvyi Rih district in the context of blended learning in the context of sustainable development of society.

4. Results

Blended learning involves traditional classroom training with online learning; online learning with the possibility of contact with a teacher; simulation with structured courses; on-the-job training with some informal classes; management coaching with distance learning activities [35]. In Ukraine, various blended learning models are currently being implemented that allow for the most appropriate combination of group learning with independent study, small group work, technology integration, and a combination of face-to-face, synchronous, and asynchronous distance learning. It is important to ensure personalization of learning, take into account the individual needs of each participant in the learning process, and promote their high expectations of the learning process. The organization of blended learning requires careful selection of learning content, the use of modern technologies, and the creation of an effective learning environment.

4.1. Use of video materials and interactive tools

To provide asynchronous learning, teachers/lecturers widely use video lessons created by themselves or selected from the Internet. By creating video lessons, they can demonstrate appropriate teaching methods and solving typical problems. Among the most popular platforms and tools that are most often used, YouTube [36] is the most popular. 100 % of respondents use the lessons they find that are useful. 37 persons (43.0 %) said that they periodically create or upload their own lessons to YouTube.

This is due to the possibility of providing easy access to video lessons for students, using the platform's video editor to add explanations, animations, and other elements. Very often, teachers/lecturers record live online lessons in Zoom (42 persons, 48.8 %), Google Meet (12 persons, 14 %)), or Microsoft Teams, which can be used for later viewing. In this case, they use the functions of the on-screen part and annotations to explain various concepts in detail. Teachers who do not record lessons in a blended learning environment mentioned the following reasons: fewer students participate in the lesson if the recording is made public later. Some students are embarrassed to know that their answers are being recorded and will be made public, even within the classroom. Recording impairs access to the network for some students, especially in rural areas, areas with significant destruction due to war, etc.

For future teachers to be able to freely create video lessons that are understandable to students, they need to prepare them in advance by completing similar tasks.

Some students noted that they used the Khan Academy platform (17 persons, 19.7 %), which has a built-in video editor and other tools, to create video lessons and study subjects. Teachers often used the Geogebra [37] dynamic math system to create video lessons, including interactive demonstrations and graphs (32 persons, 37.2 %). The teachers interviewed noted that Camtasia and Screencast-O-Matic, although they have free versions, were not used to record the screen and edit the video, add tips, animations, and sound.

Teachers widely use virtual whiteboards, such as Jamboard (63.1 %), Clever Maths (27.4 %), and Zoom Whiteboard (79.8 %), to prepare and deliver online lessons (see figure 1). Some teachers reported positive experiences with Miro (6.0 %), One Note (9.5 %) and Idroo (20.2 %) virtual whiteboards (figure 1). As practice has shown, a particularly high learning effect is achieved if participants in the learning process write synchronously on the board using a graphic tablet, special styluses, etc. Even if there is a multimedia whiteboard in the classroom, it is better to use virtual whiteboard software to ensure online collaboration. Virtual whiteboards in education can be used to simplify teaching, make explanations more accessible, and engage students in collaboration by providing different levels of access. It is convenient to use a virtual whiteboard to create concept maps or diagrams to visualize the connections between different topics.
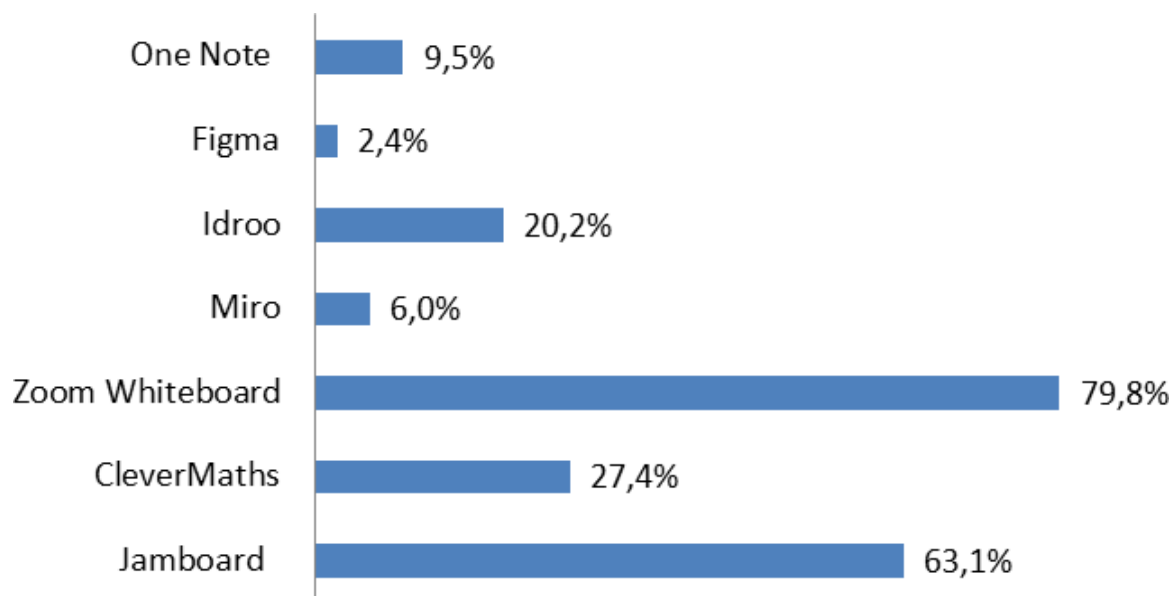

Figure 1. Statistics on the use of virtual whiteboards by math teachers in blended learning.

Padlet, an online collaboration tool, is widely used (40.7 %). Using Padlet, students create, add and discuss various tasks. The use of these interactive tools can make it easier for students to learn new things, giving them the opportunity to master the materials more efficiently.

From our own experience of training future mathematics teachers, we can note that an increase in the level of methodological competence can be achieved if online lessons are developed by a group of students using one textbook. Then students, discussing their own lessons with colleagues, will realize the importance of ensuring continuity, implementing intra- and interdisciplinary connections. The developed lessons, along with other selected visualizations, were placed in an e-learning course on the Moodle platform.

4.2. Use of virtual simulations, workshops and laboratories

Teaching mathematics in the context of sustainable development of society is relevant in the context of STEM education, successful mastery of future IT specialties, etc. [38–40] Simulations [41–44] and virtual laboratories [45, 46] provide students with the opportunity to experiment, learn, and visualize natural and mathematical concepts. Such tools are especially useful when implementing STEM approaches in education. Among the popular platforms, we note PhET Interactive Simulations and GoLab (Global Online Science Labs for Inquiry Learning), which have an interactive and intuitive interface and provide a large number of free simulations in physics, chemistry, biology and mathematics, including game elements. The study considers the scientific and theoretical underpinnings of immersive technologies in mathematics teaching, as well as methods for using the AR-Book application [47].

Using these platforms, you can personalize the educational trajectory of each student. Participants in the educational process will choose a convenient time and pace for studying the material.

Before using a particular simulation, the teacher/educator should establish the purpose of the application, using leading questions to encourage students to think critically about it. Körtesi et al. [48] focus on learning and teaching mathematics and analyze the role and usefulness of ICT tools in education, such as computer algebra systems and dynamic geometry systems in the implementation of active and innovative teaching methodologies related to sustainable STEAM education.

Among the specialized programs and tools for teaching mathematics, Ukrainian teachers most often use the visual and interactive platform GeoGebra (32 persons, 37.2 %), specialized in geometry, algebra, trigonometry, and calculus, to study specific mathematical topics. Geogebra has not only interactive geometric object designers, but also virtual laboratories for learning algebra, geometry, statistics, and other areas of mathematics. A much smaller share uses Wolfram Mathematica (9 persons, 10.5 %), GRAN educational and methodological complex (12 persons, 14.0 %) and SageMath (6 persons, 7.0 %). Desmos is widely used by math teachers in their teaching practice (41 people, 47.7 %). The results of the survey are presented (figure 2).

4.3. Game technologies for learning

Gaming platforms are a convenient tool for creating educational games [49] aimed at consolidating math knowledge. It is an effective way to engage students and make learning fun. Pertegal-Felices et al. [50] compare the impact of the Kahoot tool on the training of teachers and students of computer engineering for sustainable development of society. To ensure quality education, the authors make proposals for gamification using ICT to increase the likelihood of success and sustainability of educational institutions.

LearningApps as a multifunctional platform is used to create interactive exercises. It is very popular among domestic teachers/lecturers because it is easy to use, allows you to quickly create different types of exercises for active learning and testing the level of students. The WordWall application is similar to the interactive environment of LearningApps, but has more templates
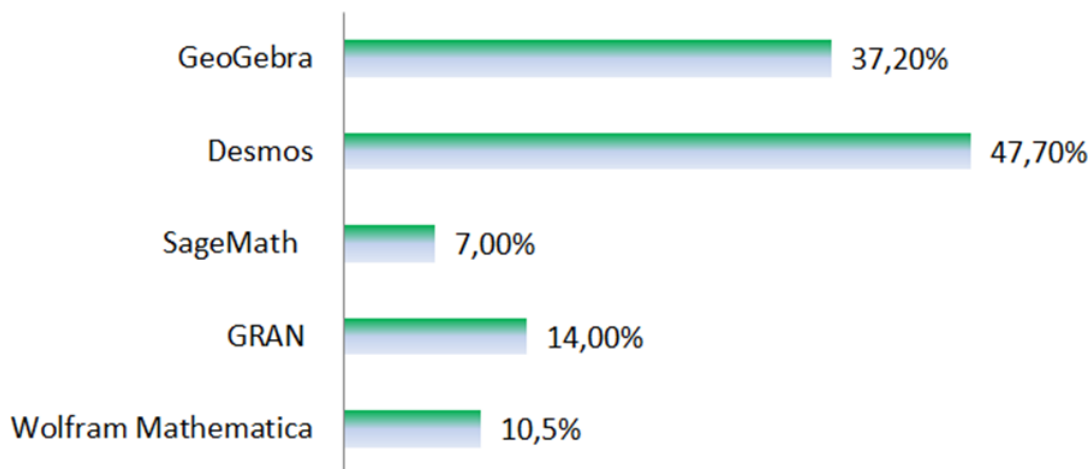
ICSF-2024

IOP Publishing

IOP Conf. Series: Earth and Environmental Science **1415** (2024) 012013

doi:10.1088/1755-1315/1415/1/012013

Figure 2. Statistics on the use of specialized programs and tools in teaching mathematics.

and functions. WordWall interactive exercises can be played on any web-based device, such as a computer, tablet, phone, or interactive whiteboard.

Kahoot allows you to create quizzes and question-and-answer games that can be used to test knowledge on various math topics and for formative assessment [51]. Quizizz is similar to Kahoot, allowing you to create question and answer games, but with a greater emphasis on the independent pace of students. It is advisable to combine surveys and the use of a smartphone with the online application Mentimeter.

53 teachers (61.6 %) reported using LearningApps exercises, 17 (19.8 %) – WordWall, 14 (16.3 %) – Kahoot, 6 teachers (7.0 %) – Mentimeter.

The following platforms are practically not used by Ukrainian teachers. Prodigy offers an online game that combines math tasks and adventure gameplay. The tool uses adaptive learning. Math Playground contains a variety of educational games, tasks, and puzzles to help students consolidate their math knowledge. Coolmath Games offers a large selection of math games that promote logical thinking and problem solving. Hooda Math offers a number of educational games focused on different sections of math.

Graphics and gamification can play a key role in creating an engaging and effective learning experience in education [52]. They help to create a stimulating environment in which learners are motivated to acquire new knowledge. This happens through the visualization of abstractions, gamification of tasks, and the use of games with a logical load. Appropriate gamification ensures personalization of learning by adapting content and tasks to the individual needs of students. Instant feedback is important, allowing students to see the results of their actions and improve their skills.

4.4. Using collaboration and idea sharing platforms
Among a number of free collaboration and idea-sharing platforms that can be used in education, Google Workspace and Microsoft Teams are popular among teachers/educators. Google Drive, Google Docs, Google Sheets, and other Google Workspace tools allow you to create, edit, and collaborate on documents and spreadsheets in real time. More than half of the teachers surveyed said that Google Meet is their preferred tool for online lessons (63 persons, 73.3 %).

Zoom is a video conferencing platform that allows teachers and students to communicate and conduct online lessons. In secondary education, teachers say they use the free version (71 persons, 82.6 %).

Platforms such as Slack, Discord, Trello, Asana allow students and teachers to work together,

exchange ideas, create joint projects, and provide a user-friendly interface for real-time or asynchronous collaboration. However, these resources are not yet used by the teachers surveyed.

Organizing open discussions and interactions through online forums and discussion platforms can greatly enrich the learning process. For this purpose, it is advisable to create thematic forums, highlighting thematic sections or topics according to the sections of mathematics, so that learners can more easily find and discuss specific issues. It is important to promote the activity of participants by encouraging them to comment, add to and express their own opinions. It is advisable to establish a reward or rating system for active participants. The teacher should maintain an open dialog. In particular, to engage students in discussion by asking somewhat provocative questions, questions that are of interest, will stimulate their thinking and analysis. It is also worth considering delegating roles, such as moderator, to help organize and support discussions. Interactive online tools such as commenting, rating, or collapsing threads for easy navigation should be used. It is important to promote constructive communication and respect for the ideas of other participants.

Allow forum participants to add graphics, videos or other multimedia to better define their issues or illustrate solutions. It is advisable to promote collective problem-solving, stimulate discussion and exchange of different approaches to solving problems. The use of these strategies will facilitate active interaction and joint learning among participants through online forums and discussion platforms.

4.5. Use of e-learning systems

The models of blended learning that are currently used in the training of future teachers and in the professional development of existing teachers also differ due to the use of learning support systems such as Moodle, Google Classroom, and others. Open courses hosted on MOOC platforms are increasingly being used for training. The use of e-learning platforms can greatly facilitate the organization of materials, assignments and tests in training. Moodle is an open platform for creating e-courses. The advantages of using the platform and new opportunities are described by Mintii et al. [53]. Educators can download materials, create assignments and tests, and use forums for discussions. Although the e-learning system is recommended for higher education institutions and schools, we have not seen any reports in the questionnaire about the use of Moodle in secondary education institutions.

Most secondary education institutions use Google Classroom as an integrated part of Google Workspace, where teachers can create classes, add assignments, materials, and tests (71 persons, 82.6 %) .

Education departments and a large number of Kryvyi Rih schools cooperate with HUMAN, a Ukrainian ed-tech company that develops and implements products for the digitalization of the Ukrainian educational process, taking into account different levels of logistics and digital literacy in educational institutions. HUMAN provides comprehensive digitalization of educational institutions by consolidating tools for organizing the educational process, communication and analytics in a single system. As a result, the institution receives tools for full-time and distance learning, as well as transparent statistics of the educational process.

Canvas is an e-learning platform that allows you to create courses, assignments, tests, and communicate with students. According to respondents, Canvas is increasingly being used in educational institutions.

Some teachers said that they use the ability to create classes in GeoGebra as an interactive platform as an auxiliary tool. Teachers also mentioned creating courses using social media. The national educational platform Vseosvita (over 3.5 million registered users) provides teachers with a library of teaching materials, tools for designing lessons, tests, web quests, and the ability to keep electronic journals. 63 people (73.3 %) regularly use the materials of the Vseosvita educational platform, and 52 teachers (60.5 %) use the materials of the Na Urok educational

platform.

When choosing a platform, it is important to take into account the needs and capabilities of students, as well as to determine which one best suits the teaching methods. Each of these platforms has its own advantages and opportunities for creating an effective learning environment. Therefore, future teachers should develop methodological competencies in the process of training to use these and potentially possible e-learning platforms in teaching students.

Tracking the progress of students and providing feedback through assessment systems should be an effective way to develop them and improve the quality of education. Let's consider strategies and tools that can be used for this purpose. It is advisable to use electronic platforms to create tasks and tests. For example, Google Forms, Moodle, or other learning management systems. Collecting data from such tasks can automate assessment and allow you to analyze the results. At the same time, use the functions of automated report generation, which can provide an overall picture of the progress of students. Such reports can include average scores, time spent on tasks, and other metrics. It is important to define clear evaluation criteria and use rubrics to assess different aspects of the work. This will allow students to better understand what is expected of them and provide specific feedback.

It is advisable to introduce different types of assessment to evaluate the quality of students' abilities and achievements, instead of limiting them to numerical grades. It is extremely important to take into account the individual characteristics of students when determining progress, to apply individualized tasks and assessments for each student. It is important to use reminder and task tracking systems to ensure that students are able to plan their time and complete their work on time. Thanks to these strategies and tools, it is possible not only to effectively track the progress of students, but also to provide them with constructive feedback for further development.

5. Conclusions

The successful use of digital technologies in education will ensure the achievement of the Sustainable Development Goals.

Blended learning, which combines traditional methods and digital technologies, can significantly improve the training of students by promoting the development of their skills and new teaching methods. This will contribute to the achievement of the Sustainable Development Goals. For the effective implementation of blended learning in training, it is advisable to integrate open online resources for the study of individual disciplines. Creating and completing interactive exercises and tasks is best organized through special platforms.

It is advisable to systematize virtual lectures and webinars, where experts can present new teaching methods or demonstrate the use of digital tools in teaching. It is important to ensure that students work practically with digital tools. It is necessary to use remote collaboration functions so that students can work together to solve tasks and solve problems. Creating online communities to discuss important topics, share ideas and resources will help build teamwork skills. In particular, through the use of forums, social networks or specialized platforms. To do this, you can provide students with feedback on their work through online platforms, taking into account both quantitative indicators and qualitative comments. This can apply to individual assignments or collective projects.

The use of adaptive technologies to individualize learning will help provide students with materials and tasks according to their needs and level of knowledge [54–56]. Blended learning allows students to acquire traditional knowledge while simultaneously becoming familiar with modern teaching methods and digital tools. It is also important to provide sufficient support and training for teachers to successfully implement these approaches. Maximizing the potential of artificial intelligence technologies in education and increasing public trust in them requires more detailed work.

ICSF-2024

IOP Publishing

IOP Conf. Series: Earth and Environmental Science **1415** (2024) 012013

doi:10.1088/1755-1315/1415/1/012013

In the future, in the context of ensuring the achievement of the Sustainable Development Goals, it is advisable to explore the prospects for realizing the potential of artificial intelligence technologies in education and increasing public trust in them.

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ICSF-2024

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