Vol. 12, No. 1, pp. 281-293, 2022 DOI: 10.23960/jpp.v12.i1.202222

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpp/

Science Teacher's Perception of Digital Technology-Based Learning in the 21st Century

Media Roza[1,*], Lufri[2], Andromeda[3], Fatni Mufit[4]

[1]Department of Sciences-Physics, Universitas Islam Negeri (UIN) Imam Bonjol Padang, Indonesia

[2]Department of Biology Education, Universitas Negeri Padang, Indonesia

[3]Department of Chemistry Education, Universitas Negeri Padang, Indonesia

[4]Department of Physics Education, Universitas Negeri Padang, Indonesia

*Corresponding email: mediaroza@uinib.ac.id

Received: 02 March 2022 *Accepted: 30 March 2022* *Published: 15 April 2022*

Abstract: Science Teacher's Perception of Digital Technology-Based Learning in the 21st Century. Objective: The research aims to identify science teachers' perceptions of digital technology-based learning in the 21st century. **Method:** This type of research is survey research. Perception data was collected through questionnaires and interviews of 30 science teachers in West Sumatra. Data analysis uses descriptive analysis. **Findings:** It was found that the main components determining the success of digital technology-based science learning are competence, effort, and teacher commitment. Teachers are greatly helped to prepare learning plans, choose teaching materials and media, carry out learning, and evaluate with digital technology. This affects the student's learning process and outcomes. Students feel interested, excited, and enthusiastic. **Conclusion:** 21st-century skills can be trained through learning based on digital technology. These findings can serve as a basis in determining the models and media of science learning based on digital technology in the 21st century.

Keywords: perception, digital technology, 21st-century skills.

Abstrak: Persepsi Guru Sains Terhadap Pembelajaran Berbasis Teknologi Digital di Abad 21. ***Tujuan:*** *Penelitian ini bertujuan untuk mengidentifikasi persepsi guru sains tentang pembelajaran berbasis teknologi digital di abad 21.* ***Metode:*** *Jenis penelitian adalah penelitian survei. Data persepsi dikumpulkan melalui kuesioner dan wawancara 30 guru sains di Sumatera Barat. Analisis data menggunakan analisis deskriptif.* ***Temuan:*** *Ditemukan bahwa komponen utama penentu keberhasilan pembelajaran sains berbasis teknologi digital adalah kompetensi, usaha, serta komitmen guru. Guru sangat terbantu menyiapkan rencana pembelajaran, memilih bahan ajar dan media, melaksanakan pembelajaran, serta melakukan evaluasi dengan adanya teknologi digital. Hal ini berdampak kepada proses dan hasil belajar siswa. Siswa merasa tertarik, senang dan antusias.* ***Kesimpulan:*** *Keterampilan abad 21 dapat dilatihkan melalui pembelajaran berbasis teknologi digital. Temuan ini dapat dijadikan dasar dalam menentukan model dan media pembelajaran sains berbasis teknologi digital di abad 21.*

Kata kunci: *persepsi, teknologi digital, keterampilan abad 21.*

To cite this article:

Roza, M., Lufri., Andromeda., & Mufit, F. (2022). Science Teacher's Perception of Digital Technology-Based Learning in the 21st Century. *Jurnal Pendidikan Progresif*, *12*(1), 281-293. doi: 10.23960/jpp.v12.i1.202222.

INTRODUCTION

The world is currently living in the industrial revolution era 4.0, which is the era where the digital industrial world has become a paradigm and reference in the order of life. The era of the industrial revolution 4.0 comes at the same time as the era of disruption. The development of information, technology, and digitalization in the 4.0 industrial revolution has led to a new paradigm shift in education (Griffin et al., 2012; Lavi et al., 2021; Phito et al., 2019; Shidiq & Permanasari, 2020). The demand in this era is to produce human resources that have 4C skills, namely critical thinking and problem solving, collaboration, communication, and creativity. To achieve this, education must be able to integrate knowledge skills, skills, and attitudes, as well as mastery of information and digital technology with classroom learning, including in science learning. Education is the main key in the development of technology that can cause changes, both in aspects of curriculum, education system, and educational philosophy (Aldila et al., 2020; Darmaji et al., 2021; Roza, 2018). The OECD (2010) shows that technology is an integral part of accessing high-level competencies as a 21st-century skill (Fatimah & Santiana, 2017).

Classroom boundaries and time are no longer barriers to learning nowadays. Various learning resources can be accessed online through a computer or smartphone. An innovative digital-based learning environment connects students' knowledge and understanding with global developments (Fletcher et al., 2020; Florea, 2019). The 21st century demands teacher innovation in science learning, such as digital-based learning, e-learning, virtual classrooms, interactive multimedia, computer-based learning (Fatimah & Santiana, 2017; Fuller & France, 2016; Jannah et al., 2020; Mulhayatiah et al., 2020)

Digital technology can help science teachers to create activities that are interesting and by the characteristics of students. Today's students referred to as generation Z are easier to update and get information with the help of technology, even students already get the material before the teacher explains it in class. Generation Z is more active and directly involved in the learning process (Hussin, 2018; Kozinski, 2017). Students can undertake collaborative work and connect with other students more readily because of the use of technology in this period. To be able to do this, science teachers need to have a proper perception of digital-based learning. Teachers' perceptions toward digital technology are critical since they are a primary factor of how well digital technology is integrated into the learning process. Positive perception will help teachers to integrate digital into learning (Qasem & Nathappa, 2016).

Studies of the use of digital applications in learning have been shown to improve learning outcomes. Some research suggests that by mastering digital technology science teachers can design innovative learning to train students' scientific literacy and overcome misconceptions. Science learning consists of many materials related to the application of community technology in everyday life. Presentation of material in audio-visual form with the help of digital technology will be more effective (Anwar et al., 2020). Budiarto et al., (2020) found that students have a positive view of the use of multimedia in learning and student learning outcomes for the better.

Students who learn to use digital literacy-based learning have different learning outcomes than those who learn to use traditional learning methods (Herlina, 2020). Hernani & Mudzakir, (2010) concluded that the process skills of grade VII junior high students improved after using digital literacy-based learning. Assessment of students' character using digital technology using websites can increase students' learning interest. Using assessments from the website can train independence, liveliness, and a positive attitude in learning (Darmaji et al., 2021; Kurniawan, 2017). Since the outbreak of the

Coronavirus Disease (Covid-19) pandemic, learning based on digital technology is the right choice. The availability of teaching materials based on digital technology can be a solution in place of science experimentation activities during distance learning as well as actively involving students in learning (Puspitasari & Mufit, 2021). Mastery of teachers on digital technology can help present learning materials contextually and audio visual-based so that learning can take place in an interesting, interactive, and participatory (Anggraeni, 2019).

According to some research, there are still challenges in integrating digital technology into education. Not all teachers have been able to employ digital technology in the classroom due to a lack of knowledge, skills, training, confidence, and facilities (Mirzajani et al., 2015). The lack of computer support and information technology, teacher teaching experience, pedagogy, skills and practices, and the development of teachers' professional abilities in integrating digital technology in learning are all factors that contribute to the low use of digital technology in learning (Jannah et al., 2020). Mulhayatiah et al., (2020) mentioned that learning media that are often used by teachers is PowerPoint as the main medium, then the use of electronic references, and interactive multimedia. The main reason teachers have not been maximal in developing technology-based media is the lack of training to develop digital integrated media that are associated with pedagogical competencies.

Skills in using technology, especially computer technology, have not been evenly distributed among science teachers. Some teachers have mastered computers but are less supported by pedagogical competence and professional competence (Herlina, 2020). The rapid development of digital technology requires teachers to be able to adapt learning activities with the development of digital technology. Teacher awareness in participating in training in the use of digital information technology in learning is still lacking (Gómez-Trigueros et al., 2019; Gudmundsdottir & Hatlevik, 2018). Teachers have pedagogical knowledge and digital technology content that is still lacking, and teachers are dissatisfied with their digital technology skills (Cabero & Barroso, 2016). Teachers' adherer to digital technology also affects students' learning interests. This influence is greater than the influence of learning management on students' learning interests (Landa et al., 2021).

Perception is an integrated activity in an individual. Perception can be expressed because of the presence of the stimulus, feelings, thinking skills, and experiences (Atkinson, et al., 1996). Therefore, it is necessary to examine how the perception of science teachers towards learning based on digital technology. Because teacher perception is a major predictor in determining the successful application of digital technology in science learning. Digitally ready teachers will be able to prepare materials, media, and learning activities creatively and innovatively. The teacher's skills, confidence, and spirit will increase. The success of teachers in integrating digital technology into learning will be greater, in other words, the quality of science learning is getting better. This will have a positive impact on students' learning activities and achievements (Mundy et al., 2012; Munyengabe et al., 2017; Qasem & Nathappa, 2016).

Science teachers' perceptions of digital technology include aspects of instructional design, management of the learning environment, innovation, and creativity, as well as communication and assessment of learning (UNESCO, 2012). Science teachers' perception of digital technology-based learning may be different from one teacher to another. Perception of digital technology can be influenced by teacher competence and available infrastructure (Jannah et al., 2020).

The study will look at how science teachers perceive digital technology-based learning. The goal of this research is to discover, examine, and describe issues about the use of digital-based technology in

science education in West Sumatra. This study examines science instructors' perception toward digital-based learning to address challenges that still exist in science education in Indonesia and to provide novel solutions for employing digital technology in the twenty-first century. The findings of this study are predicted to contribute to increasing the quality of science learning and developing successful digital technology-based learning innovations.

METHODS

The survey research approach was used in this study, which identifies science teachers' perceptions of digital technology-based learning in the 21st century. The research was conducted in mid-2021 on science teachers at high schools in West Sumatra. The selection of samples is done randomly sampling. Respondents are not chosen based on their age or term of employment. There were 30 science teachers from 30 schools involved as research respondents. The instruments used are questionnaires and interview guidelines to determine the perception of science teachers towards learning based on digital technology.

Instruments modified from ICT-enhanced Teacher Standards for Africa (ICTeTSA) (UNESCO, 2012), because it is following the essence of science learning in the 21st century. And each standard domain has its competencies/ performance indicators relating to the minimum knowledge, skills, and attitudes expected of the 21st century. The instrument variables are divided into four categories: (1) instructional design, (2) creating and managing an effective learning environment, (3) facilitating and inspiring learning, innovation, and creativity, and (4) learning and communication assessment (Jannah et al., 2020).

Interview guidelines are semi-structured. Interviews are conducted to get a more detailed picture of the subject of the research and personal information (Creswell, 2012). All questions amounted to 13 items related to teacher perception of 4 aspects of digital technology utilization. The four aspects are instructional design aspects consisting of 4 questions, aspects of creating and managing an effective learning environment consisting of 4 questions, aspects of facilitating and inspiring learning, innovation, and creativity consisting of 2 questions, and aspects of learning and communication assessment consisting of 3 questions.

The instrument used is validated by 2 experts (expert judgment). Instrument validation includes content validation and constructs validation. Measurement of instrument reliability using the Alpha Cronbach formula. According to Sugiono (2014), an instrument is declared reliable if the confession reliability is at least 0.6. Reliability test with Alpha Cronbach using SPSS 19. The validity of the instrument in this study was 4.3 with a very valid criterion, and reliability was 0.66 with a reliable criterion. So that the instruments that have been made are worth using.

The data analysis techniques used are data tabulation, data presentation, and conclusion withdrawal. Data tabulation is done to classify interview results into data tables to find answers from each respondent. The data display is used to present the results of identifying four aspects related to digital-based learning. The conclusions were drawn to determine the final results of research questions from discussions related to the perception of science teachers.

RESULT AND DISCUSSIONS

Science Teacher's Perception of the Benefits of Digital Technology in the Learning Design Process

The pedagogical knowledge reveals the science teacher's view of the capacity to use digital technologies in the learning design process. Teachers must have pedagogical knowledge on how to organize and implement learning activities using digital devices. Under the opinion of Gura

& Percy, (2005) and Al-Awidi & Aldhafeeri (2017) states that teachers must have the skills and pedagogy to use technology, as well as have the willingness to integrate technology in learning. In this research, the aspects seen are how knowledge about digital technology, the availability of digital-based technology facilities in schools, the benefits of digital technology in designing the learning process, and the use of digital technology in science learning.

According to the results of questionnaires and interviews, 73% of science instructors are already familiar with digital technology, which includes computer hardware, mobile phones, electronic devices, internet networks, applications, and social media. To utilize digital technology in science learning activities need to be supported by the availability of digital-based technology facilities in schools. In this case, obtained data as seen in Table 1 below:

Table1. Facilities of digital technology

No.	Facilities	Percentage
1	Complete	66,7%
2	Computer and LCD projector	16,3%
2	Computer/laptop only	10 %
3	There is no internet network yet	7%

The data in Table 1 shows that 66.7% of teachers state that facilities for learning using complete digital technology are available. Existing facilities in the form of computers/laptops, LCD projector, multimedia, android, and internet network. Teachers who mentioned that in school already available computers and LCD projectors 16.3%. While a small percentage of teachers state that the facilities available for learning based on digital technology are still lacking. 10% of teachers state that only computers/laptops are available, and 7% state that the internet network is not yet available in schools. Based on interviews it is known that teachers are willing and eager to carry out science learning using digital technology. Relevel with the results of Al-Awidi & Aldhafeeri (2017), teachers are also well-prepared for the implementation of digital curriculum, according to studies, both in terms of technical and pedagogical readiness. The availability of complete facilities does not always guarantee the successful application of technology in education. But the teacher factor has an important role in the integration of technology, which determines success in every educational innovation. Teachers' attitudes, beliefs, perceptions, and behaviors all play a role in how well digital technology is integrated into the classroom.

Digital technology in designing learning has been put to good use by science teachers. This is seen from the results of the study as seen in Table 2 below.

Table 2. Utilization of digital technology

No.	Utilization of Digital Technology	Percentage
1	Prepare lesson plan, prepare materials, present materials, and assessment	80%
2	Set up lesson plane only	3,3%
3	Present material only	16,7%

The data in Table 2 shows that most teachers (80%) already utilize digital technology in science learning. Preparing lesson plans, preparing materials, presenting materials, and administrating assessment results is done by utilizing digital technology, no longer conventional. While 3.3% of teachers only use digital technology to prepare lesson plans by looking for examples of lesson plans over the internet. 16.7% of teachers prefer to use digital technology to present learning

materials, namely by showing slides/learning videos. These results are relevant to research conducted by Jannah et al. (2020) that the teacher's perception of the use of digital technology is good, teachers are using digital technology for learning activities, ranging from the preparation of lesson plans, waste teaching materials, media, and evaluation.

Based on research also obtained information that science teachers utilize digital technology depending on the material discussed 46.7%, using digital technology when it requires video presentation by 46.7%, every learning using digital technology 3.3%, and using digital technology when internet access is smooth 3.3%. These results are relevant to research conducted by Fatimah & Santiana, (2017) that teachers have utilized digital technology to devise learning designs and learning processes. Teachers utilize technology to help students learn in a way that is appropriate for the time, material, and circumstance. Teachers also use technology to create educational materials, monitor learning, and conduct practical learning. The results of Pal & Patra (2021) also showed that video-based learning positively corresponds to student perception and the proper use of digital technology systems makes learning effective.

Based on the results of the interview it is known that teachers need special training related to digital-based learning media creation skills. Generally, teachers use learning media that are already available on youtube. This is relevant to the solution suggested by du Plessis & Webb (2012) that it is necessary to conduct training according to the needs of teachers, the training is ongoing, school-based, and monitoring and managing the process every week.

Teachers' Perceptions on Using Digital Technology to Create and Manage Effective Learning Environments.

The perception of science teachers about how to create and manage an effective science learning environment by utilizing digital technology can be seen from the aspect of mastery/skills to digital technology, digital technology to manipulate the condition of less-skilled teachers, and initiatives to raise awareness of digital technology expertise. Based on the data obtained information that the skills of science teachers in using digital technology can be seen in Figure 1.

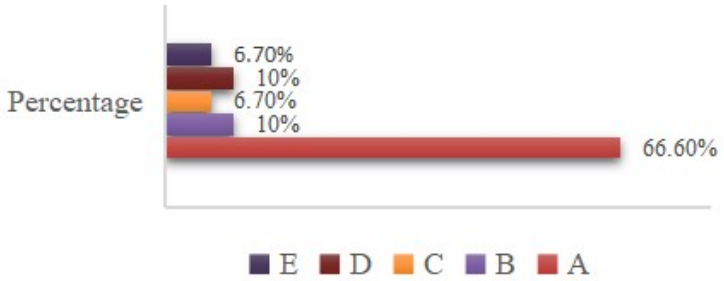

Figure 1. Mastery of digital technology

Figure 1. Shows mastery of digital technology, where line A explains designing learning, preparing materials media, delivering tasks and evaluation, B explains setting up a learning video media, C explains preparing a lesson plan and evaluation, D explains assign tasks, and E explains to create a presentation slide. These results show that in general teachers already have a good mastery of digital technology. 66.6% of science teachers are already skilled in

utilizing digital technology to design learning, prepare materials, media, deliver assignments and evaluations. 10% of teachers are skilled in using digital technology to prepare to learn video media, 6.7% prepare lesson plans, and evaluations, 10% assign assignments, and 6.7% create presentation slides. The existence of digital technology can also help teachers in overcoming teacher weaknesses or lack of facilities in schools. Some aspects that can be overcome by the use of digital technology are seen in Figure 2 below:

The data in Figure 2 shows that science teachers have a perception that digital technology can overcome shortcomings. Point A shows

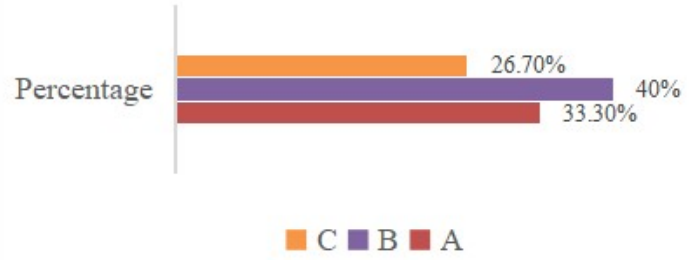

Figure 2. Benefits of digital technology (A, B, C explain demonstrate experiments, learning media, and mastery of materials)

33.3% of teachers find it helpful in the mastery of materials, Point B shows 40% of teachers state that utilizing digital technology can help teachers in overcoming difficulties to provide learning media, and point C shows 26.7% of teachers can utilize digital technology to demonstrate or demonstrate experiments in science learning.

The utilization of digital technology in learning, creating material content, and digital modeling increases the creativity and confidence of teachers. This affects the quality of learning and puts more value on the skills of future students Herro & Quigley, (2016). The results of this study are fIn line with the findings of Altýnay-Gazi & Altýnay-Aksal, (2017) which states that the utilization of digital technology can increase teacher confidence, improve communication skills and improve the quality of learning. The utilization of digital technology in learning can also improve the understanding of student concepts according to the demands of the 21st century (Mufit et al., 2020).

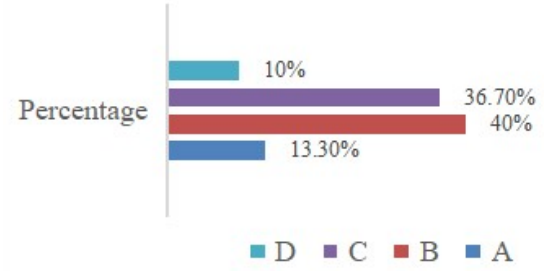

Figure 3. Teacher's Efforts to Use Digital Technology (A, B, C, dan D explain learning technology seminar, learning technology seminar, learning media development workshop, and Others)

Recognizing that science teachers have shortcomings in the mastery of digital technology in learning, teachers' efforts in growing awareness of the mastery of digital technology have been widely done, either by attending seminars, training, or workshop. Among the efforts of the teacher can be seen in Figure 3 below:

Teacher efforts to improve the mastery and skills of using learning technology include 40% participating in training on an e-learning/google classroom (point B). Point C shows 36.7% attended IT-based learning media development workshops, point D shows 13.3% attended seminars on learning technology, and point A shows 10% of other activities such as teacher deliberations of subjects or discussions with other teachers in terms of creating learning media. Teachers feel that the opportunity to take training in developing learning media based on digital technology still needs to be improved. This is following the results of research conducted by Herlina, (2020) which found that teacher mastery in terms of video applications, making learning videos, and editing learning videos still needs to be improved.

From the interview also obtained information that in addition to attending seminars, training, or workshops related to digital technology in science learning, teachers also participated in online learning applications, such as home learning, teacher room, PhET Simulation, and Branly Indonesia. While online learning applications such as Kipin school 4.0, Icando, Quipper school, Smart classes, Zenius, Sisco Webex are rarely used by science teachers. The findings are relevant to the results of Al-Awidi & Aldhafeeri, (2017) research that found a similar tendency, namely teachers have a desire to acquire technological and pedagogical knowledge to be able to integrate digital technology effectively in the curriculum. These results show that teachers are ready to integrate digital technology into learning. The government needs to hold even and continuous training or workshops to improve teacher readiness in utilizing digital technology.

Perception of Science Teachers to Facilitate, Inspire, Innovate, and Creativity learning based on Digital Technology

Many found positive impacts and there were also negative impacts in the utilization of digital technology in science learning. Many topics in science learning require digital visualization to share material with students. The perception of science teachers in facilitating, inspiring, innovating, and creativity in the learning of science-based on digital technology can be seen from the aspect of learning situations in using digital technology, and problems that arise in the use of digital technology. The results showed data that the situation of learning science using digital technology can be seen in Table 3 below:

Table 3. The situation of learning science using digital technology

No	Learning situation
1	Active and enthusiastic in learning
2	Have a high curiosity
3	Quickly respond to digital stimulus
4	Self-study and grouping
5	Creativity increases
6	Accustomed to observing, asking, and thinking critically
7	More focus on learning

Based on the data in Table 3 it is seen that the situation of learning science using digital technology has a positive effect. During the learning process, students are active, excited, and enthusiastic in learning compared to learning without digital technology, for example using package books or worksheets only. The use of video or PhET simulation makes students

interested and provokes curiosity. Group discussions to discuss the material presented with digital technology become more lively, communication between students increases, focuses on the material, learning to be independent and train students to get used to observing, asking questions, and finally getting used to critical thinking.

These results are relevant to a study by Portillo et al., (2020) which found that specialized digital skills are required by teachers for the development of teaching methods (creating and managing), meaningful learning activities, knowing how to use educational platforms, and structure learning. These skills are proven to be related to good student performance.

Integrating digital technology in today's science learning will make instructors more creative in designing their learning, so that learning becomes more engaging, active students, and enthusiastic. Learning can also be more effective because the way it is delivered is following the characteristics of generation Z students. Not only students who get the benefits, but teachers can also have more flexibility in designing lessons creatively (Hussin, 2018).

In addition to the benefits, there are several drawbacks to using digital technology in science education. A frequent problem is that the desire to read and write decreases, as the answer to a question can be easily found by students through internet browsing. Students view experiments that are aired through learning media such as instant and can be done quickly. Whereas experimenting takes time for processing, observation, data processing, and speaking conclusions. If the teacher gives homework, students are less able to manage their time well. These results are in line with research conducted by Jannah et al., (2020) that in addition to positive impacts also found negative effects similar to the results of this study. Another impact found was that students became lazy or moved slightly. Generation Z is more comfortable sitting for a long time in front of a computer, laptop, or smartphone.

Science Teacher's Perception of Learning and Communication Assessment in Digital Technology-Based Learning

This can be seen in scientific teachers' perception of digital technology's role in improving the learning process, as well as the skills needed to use technology to acquire 21st-century competencies. Based on questionnaire data and interviews, the average teacher's answers show that the utilization of digital technology can improve the process and outcomes of science learning. The results of the perception teacher can be seen in Table 4.

Table 4. Utilization of digital technology for the development of 21st-century skills

No	The 21st Century Skills	Percentage
1	Critical thinking, collaboration, communication, and creativity	40%
2	Critical thinking and creativity	26,7%
3	Collaboration and communication	6,7%
4	Communication and creativity	6,7%
5	Critical thinking	6,7%
6	Creativity	13,3%

Data in Table 4 states science teachers have a perception that the use of digital technology affects students' 21st-century skills. 40% of teachers agree that the four skills of the 21st century, namely critical thinking, collaboration, communication, and creativity can be improved by the proper use of digital technology in learning. Based on personal experience with the use of digital technologies in the classroom 26.7% of teachers stated effective to improve critical thinking skills and creativity, but less effective for collaboration and communication. 13.3% of teachers stated that the use of digital technology for learning can increase student creativity. 6.7%

of teachers say the use of digital technology for learning can train each of collaboration and communication, communication and creativity, and think critically only. This is in line with Spengler, (2015) who states that technology can easily help in facilitating and encouraging cooperation and communication. Students also use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions from digital information. Digital technology also encourages students to collect, evaluate, and use information in learning. Teachers feel that digital multimedia can help students build oral and writing communication abilities (Del-Moral-Pérez et al., 2019).

The utilization of digital technology also contributes to the development of student literacy. Based on questionnaires and interviews obtained data that science teachers mention some literacy that can be trained through the use of digital technology, namely science literacy, numeracy literacy, data literacy, technology literacy, and human literacy. This is in line with Spengler, (2015) findings that students can understand human, cultural, and social issues related to technology and practice legal and ethical behavior. Students can also demonstrate a good understanding of technological concepts, systems, and calculating operations through the utilization of digital technology.

■ CONCLUSIONS

Based research conducted found that mastery of learning based on digital technology has become a necessity for a teacher, including science teachers. The main components that determine the success of digital technology-based learning are the competence, effort, and commitment of teachers, and not the issue of the availability of digital devices. The performance of teachers in preparing learning plans, choosing teaching materials and media, carrying out learning, and evaluating is greatly helped by the existence of digital technology. This affects the learning process and learning outcomes of learners. Utilization and selection of digital technology in science learning following the learning style of generation Z today which is very literate to digital technology and information. Learners feel happy, enthusiastic, and the skills needed in the 21st century can be trained through learning based on digital technology. These findings can be used as the basis in creating learning innovations based on digital technology that is effective in following the characteristics and goals of 21st-century learning, to create a competitive next generation.

■ REFERENCES

Al-Awidi, H., & Aldhafeeri, F. (2017). Teachers'readiness to implement digital curriculum in Kuwaiti schools. *Journal of Information Technology Education*, *16*(1), 105-126.

Aldila, F. T., Wirayuda, R. P., Wulandari, M., & Ningsi, A. P. (2020). Description of science process skills of SMAN 10 Muaro Jambi's students on the equilibrium material on the rope. *Jurnal Pendidikan Fisika*, *9*(2), 112–119.

Altýnay-Gazi, Z., & Altýnay-Aksal, F. (2017). Technology as mediation tool for improving teaching profession in higher education practices. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(3), 803–813.

Anggraeni, H. (2019). Penguatan blended learning berbasis literasi digital dalam menghadapi era revolusi industri 4.0 [Strengthening blended learning based on digital literacy in the face of the era of industrial revolution 4.0]. *Al-Idarah: Jurnal Kependidikan Islam*, *9*(2), 190–203.

Anwar, K., Rusdiana, D., Kaniawati, I., & Viridi, S. (2020). Desain pembelajaran

gelombang untuk membentuk calon guru fisika yang terampil, berbudaya dan paham teknologi digital [Wave learning design to form aspiring physics teachers who are skilled, cultured and digital technology savvy]. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *4*(1), 26–37.

Atkinson Rita, L., Atkinson, R. C., Smith, E. E., & Daryl, J. (n.d.). BEM, & Susan Nolen-Hoeksema.(1996). *Hilgard's Introduction to Psychology.* USA: Harcourt Brace College Publishers.

Budiarto, M. K., Joebagio, H., & Sudiyanto, S. (2020). Student's view of using digital learning media in classroom activities: A case of public Senior High School in Cirebon, Indonesia. *Jurnal Pendidikan Progresif*, *10*(1), 47–54.

Cabero, J., & Barroso, J. (2016). ICT teacher training: a view of the TPACK model/ Formación del profesorado en TIC: una visión del modelo TPACK. *Cultura y Educación*, *28*(3), 633–663.

Creswell, J. W. (2012). *Educational research/ : planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson.

Darmaji, D., Astalini, A., Kurniawan, D. A., & Aldila, F. T. (2021). Students' perceptions in the use of web-based character assessment from gender perspective. *Jurnal Pendidikan Progresif*, *11*(2), 362–383.

Del-Moral-Pérez, M. E., Villalustre-Martínez, L., & Neira-Piñeiro, M. del R. (2019). Teachers' perception about the contribution of collaborative creation of digital storytelling to the communicative and digital competence in primary education schoolchildren. *Computer Assisted Language Learning*, *32*(4), 342–365.

Du Plessis, A., & Webb, P. (2012). Teachers' Perceptions about their own and their schools' readiness for computer implementation: A South African case study. *Turkish Online Journal of Educational Technology-TOJET*, *11*(3), 312–325.

Fatimah, A. S., & Santiana, S. (2017). Teaching in 21st century: Students-teachers' perceptions of technology use in the classroom. *Script Journal: Journal of Linguistic and English Teaching*, *2*(2), 125-135.

Fletcher, J., Everatt, J., Mackey, J., & Fickel, L. H. (2020). Digital technologies and innovative learning environments in schooling: A New Zealand experience. *New Zealand Journal of Educational Studies*, *55*(1), 91–112.

Florea, C. (2019). Brief analysis of sounds using a smartphone. *The Physics Teacher*, *57*(4), 214–215.

Fuller, I. C., & France, D. (2016). Does digital video enhance student learning in field-based experiments and develop graduate attributes beyond the classroom? *Journal of Geography in Higher Education,* 40(2), 193-206.

Gómez-Trigueros, I. M., Ruiz-Bañuls, M., & Ortega-Sánchez, D. (2019). Digital literacy of teachers in training: Moving from ICTS (information and communication technologies) to LKTs (learning and knowledge technologies). *Education Sciences*, *9*(4), 274-284.

Griffin, P., Care, E., & McGaw, B. (2012). The changing role of education and schools. In *Assessment and teaching of 21st century skills* (pp. 1–15). Springer.

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: implications for teacher

education. *European Journal of Teacher Education*, *41*(2), 214–231.

Gura, M., & Percy, B. (2005). *Recapturing technology for education: Keeping tomorrow in today's classrooms*. R&L Education.

Herlina, E. (2020). Supervisi akademik untuk meningkatkan kemampuan literasi digital guru SMP Negeri 2 Bungursari [Academic supervision to improve the digital literacy skills of SMP Negeri 2 Bungursari teachers]. *Juripol (Jurnal Institusi Politeknik Ganesha Medan)*, *3*(1), 26–34.

Hernani, H., & Mudzakir, A. (2010). Pengaruh pembelajaran berbasis literasi sains dan teknologi terhadap keterampilan proses sains siswa SMP [Influence of science and technology literacy-based learning on the science process skills of junior high school students]. *Jurnal Pendidikan Matematika Dan Sains*, *15*(1), 29–34.

Herro, D., & Quigley, C. (2016). STEAM enacted: A case study of a middle school teacher implementing STEAM instructional practices. *Journal of Computers in Mathematics and Science Teaching*, *35*(4), 319–342.

Hussin, A. A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies*, *6*(3), 92–98.

Jannah, M., Prasojo, L. D., & Jerusalem, M. A. (2020). Elementary school teachers' perceptions of digital technology based learning in the 21st Century: Promoting digital technology as the proponent learning tools. *Al Ibtida: Jurnal Pendidikan Guru MI*, *7*(1), 1–18.

Kozinski, S. (2017). *How generation Z is shaping the change in education. Retrieved March 18, 2020*.

Kurniawan, F. A. (2017). Pengaruh pembelajaran berbasis web terhadap motivasi dan hasil belajar siswa kelas X SMA Negeri Paguyangan pada mata pelajaran fisika pokok bahasan suhu dan kalor [The influence of web-based learning on the motivation and learning outcomes of students of class X of Paguyangan State High School on the subject of subject matter temperature and heat]. *Scientiae Educatia: Jurnal Pendidikan Sains*, *6*(1), 1–7.

Landa, Z. R., Sunaryo, T., & Tampubolon, H. (2021). Pengaruh literasi digital guru dan manajemen pembelajaran terhadap minat belajar peserta didik di SMA Pelita Rantepao [The influence of digital literacy of teachers and learning management on the learning interests of learners at Pelita Rantepao High School]. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *5*(1), 718–734.

Lavi, R., Tal, M., & Dori, Y. J. (2021). Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning. *Studies in Educational Evaluation*, *70*, 101002.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook*. Sage Publications.

Mirzajani, H., Mahmud, R., Ayub, A. F. M., & Luan, W. S. (2015). A review of research literature on obstacles that prevent use of ICT in pre-service teachers' educational courses. *International Journal of Education and Literacy Studies*, *3*(2), 25–31.

Mufit, F., Hanum, S. A., & Fadhilah, A. (2020). Preliminary research in the development of physics teaching materials that integrate new literacy and disaster literacy. *Journal of Physics: Conference Series*, *1481*(1),

12041. IOP Publishing.

Mulhayatiah, D., Suhendi, H. Y., & Windayani, N. (2020). TPACK's understanding analysis of physics teachers in using learning media. *Jurnal Pendidikan Progresif*, *10*(3), 526–533.

Mundy, M.-A., Kupczynski, L., & Kee, R. (2012). Teachers' perceptions of technology use in the schools. *Sage Open*, *2*(1),2158244012440813.

Munyengabe, S., Yiyi, Z., Haiyan, H., & Hitimana, S. (2017). Primary teachers' perceptions on ICT integration for enhancing teaching and learning through the implementation of one laptop per child program in primary schools of Rwanda. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(11), 7193–7204.

Pal, D., & Patra, S. (2021). University students' perception of video-based learning in times of COVID-19: A TAM/TTF perspective. *International Journal of Human–Computer Interaction*, *37*(10), 903–921.

Phito, V., Arief, A., & Roza, M. (2019). Pengembangan instrumen asesmen higher order thinking skills (HOTs) dalam pembelajaran fisika pada materi hukum Newton kelas X SMA/MA [Development of assessment instruments higher order thinking skills (HOTs) in the study of physics in Newton law materials grade X SMA / MA]. *Natural Science Journal*, *5*(1), 787–799.

Portillo, J., Garay, U., Tejada, E., & Bilbao, N. (2020). Self-perception of the digital competence of educators during the COVID-19 pandemic: A cross-analysis of different educational stages. *Sustainability*, *12*(23), 10128.

Puspitasari, R., & Mufit, F. (2021). Conditions of learning physics and students' understanding of the concept of motion during the covid-19 pandemic. *Journal of Physics: Conference Series*, *1876*(1), 12045. IOP Publishing.

Qasem, A. A., & Nathappa, V. (2016). Teachers' perception towards ICT integration: professional development through blended learning. *Main Issues Of Pedagogy And Psychology*, *11*(2), 20–26.

Roza, M. (2018). Penerapan model Project Based Learning untuk meningkatkan creativity and innovation skills mahasiswa [Application of Project Based Learning model to improve student creativity and innovation skills]. *Tarbiyah Al-Awlad*, *8*(2), 166–176.

Shidiq, A. S., & Permanasari, A. (2020). Chemistry teacher's perception toward STEM learning. *Proceedings of the 2020 International Conference on Education Development and Studies*, 40–43.

Spengler, S. (2015). *Educators' perceptions of a 21st century digital literacy framework*. (Doctoral dissertation, Walden University).

Sugiono. (2014). *Penelitian Manajemen (Management Research Method)*. Alfabeta.

UNESCO. (2012). *ICT-enhanced teacher standards for Africa (ICTeTSA)*. Ethiopia: UNESCO-IICBA.