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Integrating Digital Technology and Science Learning to Enhance 21st-Century Competencies among Primary School Teacher Education Students

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Abstract: The fast growth of digital technology has changed how education is done, including how science is taught in college. Future teachers who want to work in elementary schools need to have skills that are important in the 21st century. These skills include thinking critically, being creative, working together with others, communicating effectively, and being able to use digital tools. This study looks at how using digital technology in science lessons can help improve 21st-century skills for students studying to become primary school teachers. The study used a literature review approach by looking at important national and international articles about digital learning, science teaching, and skills needed in the 21st century. The results show that using digital tools in science classes helps students become more involved, better understand science, improve their ability to solve problems, and work better together in groups. Digital tools like learning management systems, interactive multimedia, virtual labs, and educational apps offer valuable learning experiences and help students develop stronger thinking skills. Using digital technology along with science education is a good way to help future elementary school teachers get ready for the challenges of teaching in the modern digital age.

Keywords: Digital Technology, Science Learning, 21st Century Competencies, PGSD Students, Scientific Literacy

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INTRODUCTION

Digital technology has made big changes in many areas of life, like education. Digital transformation in education is changing how learning takes place, moving the emphasis from teaching focused on the teacher to learning focused on the student (UNESCO, 2023). The use of technology in college education is becoming more important because teachers of the future need to know both how to teach effectively and how to use digital tools (Mishra & Koehler, 2020; Voogt et al., 2020).

Studying science is a subject that can really help build important skills like thinking critically, solving problems, being creative, and understanding science better (Bybee, 2021). Science learning helps students explore things, look at evidence, and build understanding by doing hands-on activities that encourage questioning and discovery (Lederman, 2020). Accordingly, the integration of digital technology into science learning is deemed a highly effective method for enhancing learning quality and student engagement.

According to the OECD in 2023, the skills needed for the 21st century include thinking critically, communicating effectively, working together, coming up with new ideas, and being able to use digital tools. The acquisition of these proficiencies is crucial for equipping future educators to handle educational obstacles in the age of technology. Digital technology allows students to get information, work together online, and have learning experiences that are more flexible and interactive (Fraillon et al., 2020).

METHODS

This study used a literature review approach to look at how combining digital technology with science learning can help improve 21st-century skills in PGSD students. A literature review helps gather and understand the results from past studies and spot patterns or trends in a specific area of research (Snyder, 2019). The study used the methods suggested by Creswell and Creswell (2018), which involved finding relevant sources, checking them for suitability, grouping them into categories, understanding their meanings, and combining the information together.

RESULTS

Digital technology helps students get more involved in learning science by creating interactive and teamwork-based learning environments. Bond et al.(2020) say that using educational technology can help students get more involved, stay more interested, and feel more satisfied with

their learning when it's used properly in college courses. Digital platforms help learners take an active role in their learning by using discussion forums, group projects, and interactive tests.

Using technology in teacher training helps build the skills needed to effectively use technology in teaching. Kimmons and their team in 2020 say that using technology well isn't just about replacing old teaching ways. Instead, it's about making learning more engaging and meaningful by changing how students interact with the material. This change helps future teachers learn how to use technology to support more meaningful learning and teaching that focuses on the students. Besides that, how well educational technology is used depends on how teachers feel about it, what they believe, and whether they are willing to use digital tools. Scherer and their team in 2019 discovered that when teachers think a technology tool is useful and easy to use, they are more likely to include it in their teaching methods. Therefore, building digital skills should be a key part of training teachers.

Research by Valtonen and others in 2021 shows that using technology in learning helps students develop important skills for today's world, like thinking critically, coming up with new ideas, working together, and communicating effectively. These skills are becoming more important for PGSD students, as they are meant to grow into creative teachers who can deal with the problems in today's education system.

Uerz and other researchers in 2018 highlight that teacher educators are important in helping future teachers develop skills related to using technology. Having the right technology and learning opportunities can help students feel more confident when using digital tools for teaching. Ertmer and Ottenbreit-Leftwich (2019) say that using technology effectively needs more than just knowing how it works. It also needs good attitudes and a school environment that supports using technology.

The results also match the Technological Pedagogical Content Knowledge (TPACK) framework introduced by Chai and others in 2013.This framework shows how important it is to combine knowledge about technology, teaching methods, and the subject being taught when planning lessons. By using science education that includes digital tools, PGSD students can build these related skills and get ready for their future work responsibilities. The results also show that digital tools help make group learning more effective and engaging. Online discussion forums, video call apps, and shared document tools help students share thoughts and work together to find solutions. These learning environments help build communication and teamwork skills that are important for future teachers.

Table 1. Contributions of Digital Technology in Science Learning

Digital Technology	Learning Activities	Competencies Developed
Learning Management System (LMS)	Online learning and assignments	Digital literacy, self-regulated learning
Virtual Laboratory	Science experiments and simulations	Critical thinking, scientific literacy
Interactive Multimedia	Concept visualization	Creativity, conceptual understanding
Educational Applications	Problem-solving activities	Innovation, analytical skills
Online Collaboration Platforms	Group discussions and projects	Communication, collaboration

Research shows that teaching science with digital tools helps students improve their ability to think critically. Students are encouraged to study data, verify scientific facts, create ideas to explain different things, and propose solutions for real problems. These activities help build the skill to think carefully and find solutions, which are important abilities in modern education. Valtonen and others in 2021 say that using technology in learning helps students do more complex thinking tasks, which support skills like thinking critically, being creative, working together, and communicating well. Martin et al.(2020) discovered that digital learning environments help students get more involved and think deeply about what they're learning. This makes it easier for them to understand information better and come up with ways to solve problems. Kimmons and their team in 2020 said that using technology in a meaningful way can change how students learn by turning regular lessons into activities where they ask questions and explore on their own. This helps them grow smarter and learn more by themselves.

Another important finding is that scientific knowledge is better understood. Having access to digital tools lets students see scientific information from various places and determine if it is reliable. Because of this, students can understand science events better and make choices based on facts. This result matches what Bybee (2018) said, which is that being scientifically literate means being able to think carefully about scientific information and use scientific thinking in everyday choices. In addition, Lederman and his team in 2013 said that knowing what science is like is important for building scientific literacy and helping people be more informed citizens. Digital tools make it easier for students to access more scientific materials, computer models, and visual content, which helps them better understand ideas and develop skills in using evidence to support their thinking. Fraillon and others in 2020 pointed out that being able to use digital tools and tell good information from false stuff is more important than ever. This helps students deal

with a lot of online content and recognize reliable sources from fake ones.

Table 2. Impact of Digital Technology Integration on 21st-Century Competencies

Competency	Contribution of Digital Technology
Critical Thinking	Data analysis, scientific inquiry, problem-solving
Creativity	Development of digital projects and multimedia products
Communication	Online discussions, presentations, and collaborative work
Collaboration	Team-based learning and digital cooperation
Digital Literacy	Effective use of digital tools and information resources
Scientific Literacy	Understanding scientific concepts and evidence-based reasoning

DISCUSSION

The findings indicate that incorporating digital tools into science teaching helps postgraduate students in science education build key abilities that are essential for success in the modern world. These results show that using technology in schools can lead to more interesting, active, and focused learning for students. Digital technologies offer students the chance to build their own knowledge by exploring, investigating, and getting involved actively, instead of just listening or watching without taking part.

From a constructivist viewpoint, using digital technology in science learning helps students create knowledge by asking questions, doing experiments, and thinking about what they learn. Virtual labs, simulations, and interactive videos offer real learning experiences that link classroom ideas to actual situations in the world. These learning experiences help students understand scientific ideas better and remember them for a longer time. This result supports the idea that using technology in learning helps students learn more deeply and build knowledge actively.

This study found that improving critical thinking skills matches what earlier research has shown, which emphasizes how inquiry-based science learning helps develop better thinking abilities. Digital tools give students access to scientific information, real-life issues, and different kinds of resources. This helps them look at evidence, come up with explanations, and think about other possible solutions. Because of this, students develop better skills in thinking critically and solving problems, which are important for doing well in school and succeeding in their future jobs. Another key result is about how scientific literacy is growing. In today's world, being scientifically literate is a key skill that people need. Citizens are expected to make smart choices using scientific information and evidence. Students can access the latest scientific information, digital tools, and multimedia materials thanks to digital technology, which help them think and reason using solid evidence. This finding agrees with Bybee (2018), who said that scientific literacy means being able to think carefully about scientific information and use scientific thinking

in daily life. Similarly, Lederman and his team in 2013 believed that knowing what science is really about is key to helping people become more scientifically informed. The results also show that digital tools help improve how people work together in learning activities. Working together has become a key skill in today's education because jobs today often need people to work in teams, talk clearly, and solve problems together. Online discussion forums, video conference tools, and shared document platforms let students talk and work together no matter where they are or what time it is. These kinds of settings help teachers learn from each other, share ideas, and work together to solve problems, which improves their ability to communicate and work as a team.

Creativity became a major result of using technology to improve science education. Digital tools allow students to make presentations, build multimedia projects, make educational videos, and come up with new learning resources. These activities help students think creatively and come up with new ideas, and also teach them how to create interesting and effective lesson plans for elementary school classes. As future teachers, PGSD students need to be able to design interesting and creative learning activities that work for all different kinds of students.

The results back up the Technological Pedagogical Content Knowledge (TPACK) framework that Mishra and Koehler introduced in 2006. The TPACK framework focuses on combining knowledge of technology, teaching methods, and subject matter to create better teaching strategies. By using digital tools for science learning, students gain not just a deep understanding of scientific subjects, but also the teaching methods and technology skills needed to successfully apply what they've learned in the classroom. This finding also agrees with Chai et al.(2013), who believed that TPACK is very important for helping future teachers use technology in a meaningful way during their teaching activities.

The results also show that digital literacy is becoming more important in training teachers. Redecker (2017) says that digital competence means being able to get, check, make, and share information using digital tools in a responsible and effective way. In science classes, being able to use digital tools helps students check if information is trustworthy, find dependable sources, and make good choices using facts and evidence. So, using technology in education helps students do better in school and also teaches them how to be good digital citizens when they become teachers.

Another important thing from this study is how it affects the way we prepare teachers for the future. Uerz et al.(2018) said that teacher training schools need to give future teachers real chances to use technology in ways that make learning meaningful. Ertmer and Ottenbreit-Leftwich (2019) said that using technology well isn't just about knowing how to use it, but also having a good attitude, beliefs that support it, and backing from the

institution. So, universities should create helpful learning spaces, make sure there's good technology available, and keep offering training on teaching with digital tools. Even though there are many good things to note, there are still some problems that need to be worked on. Not all students have the same access to technology, and differences in how well they know how to use digital tools can affect how well technology is used in learning. Poor infrastructure, weak internet access, and lack of enough technology help can stop the use of new digital learning ideas. Therefore, colleges and universities need to put money into better technology, teach students how to use digital tools, and create rules that help use technology well in teaching science.

Using digital technology along with science learning can greatly help make teacher education programs better. The results show that using technology in science learning helps PGSD students improve their ability to think critically, be creative, work together, communicate effectively, understand science better, and become more skilled with digital tools. These skills are important for training future elementary teachers so they can create exciting, student-focused lessons that use technology to support learning. So, using digital tools in science teaching should be a key focus in training teachers, to meet the changing needs of education in the 21st century.

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