

INFORMATION AND COMMUNICATION TECHNOLOGY LEARNING SYSTEM IN 21ST CENTURY EDUCATION

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ABSTRACT

This study aims to analyse the implementation of Information and Communication Technology (ICT) in 21st-century learning systems and its contribution to improving the quality of teaching and learning. The study employs a Systematic Literature Review (SLR) method to identify, evaluate, and synthesise findings from relevant national and international studies on ICT integration in education. The review indicates that ICT plays a significant role in fostering students' 21st-century competencies, particularly the 4C skills: critical thinking, creativity, collaboration, and communication. ICT also promotes student-centred learning, increases engagement, and supports flexible and interactive instructional practices. However, its implementation remains constrained by inadequate technological infrastructure, limited internet accessibility, insufficient digital resources, and teachers' varying levels of digital competence and pedagogical readiness. Addressing these challenges requires improved access to technology, sustainable professional development programs, and supportive educational policies. Effective and well-planned ICT integration can optimise learning outcomes, strengthen educational quality, and provide valuable directions for future research on technology-enhanced learning environments.

Keywords: ICT-based learning; 4C competencies; Learning System; Infrastructure; Teacher Training.

INTRODUCTION

21st-century education demands a transformation of the learning system to be more adaptive, flexible, and responsive to the rapid development of digital technology. This change is inevitable, as the global community has entered the era of digital transformation, which impacts nearly all aspects of life, including the way we learn, work, and interact (Mukul & Büyüközkan, 2023). However, even though digital technology, artificial intelligence, and online learning platforms have opened new opportunities to create more interactive and collaborative learning experiences, many educational institutions still face significant challenges in effectively and comprehensively implementing these technologies (Najmudin et al., 2025).

For instance, in many schools and universities, the learning system is still dominated by a conventional, teacher-centred approach. Although technology has been introduced, it is often used merely as a tool for presentations rather than as an integral part of a deep, interaction-based learning process (Østerlie et al., 2025). This has the potential to limit the development of competencies required by future generations, such as critical thinking, creativity, collaboration, and communication (4Cs), which are considered essential core competencies in 21st-century education (Zou et al., 2025).

Based on recent studies, although the integration of technology in some schools has shown positive results in enhancing student interaction and engagement, its implementation is often not systematic. It does not align with learners' needs. For instance, recent research indicates that while technology can enhance the learning experience, its use must be strategically designed to support processes of interaction, exploration, reflection, and collaboration among students. Without an appropriate pedagogical approach, technology serves merely as an accessory and does not significantly contribute to the achievement of 4C competencies (Antonio, 2025; Xu et al., 2025).

The other issue is that many teachers are not yet skilled in designing effective technology-based learning. Planning and evaluating learning that integrates technology is often not supported by sufficient data to measure its effectiveness (Consoli et al., 2023). This creates a significant gap between the potential of technology and its reality in the field. Therefore, a systematically designed and sustainable learning system is needed to accommodate the demands of 21st-century education and support the development of 4C competencies.

The educational transformation brought about by the Fourth Industrial Revolution demands fundamental changes in the learning system. The integration of digital technology and automation in the educational process is not merely to meet the demands of the times but also to create a generation that is adaptive, innovative, and ready to face global challenges. Therefore, the planning and implementation of a learning system that incorporates technology must consider learners' characteristics, the selection of appropriate technologies, and continuous evaluation to ensure that the education provided is not only relevant but also effective in achieving 21st-century competency goals.

METHODOLOGY

This study employs a Systematic Literature Review (SLR) to identify, evaluate, and synthesise prior research on information and communication technology (ICT)-based learning and 21st-century education. This approach was chosen as it provides a comprehensive understanding and minimises subjective bias in literature-based research. The research procedure follows the PRISMA guidelines, which include four main stages: identification, screening, eligibility, and inclusion. The identification process involves searching scholarly databases such as Scopus, ScienceDirect, and Google Scholar for articles using predefined keywords. Articles that meet the inclusion and exclusion criteria are then selected for further analysis.

The inclusion criteria for this study comprise journal articles published between 2015 and 2025, indexed in reputable databases, and relevant to ICT-based learning. Articles lacking a clear

methodology, unavailable in full text, or those with publication duplication were excluded from the selection. The selected articles were then classified by publication year, research methods, and study focus. This selection process aims to ensure the quality and relevance of the data to be analysed in this research. Data were collected through a documentation study that involved downloading, reading, and organising the selected scientific articles for further analysis.

The data analysis was conducted using thematic analysis, where data from selected articles were coded and grouped based on the key themes that emerged. This process includes data reduction, categorisation, and synthesis of relevant research findings. To ensure the validity and reliability of the study, source triangulation was conducted by comparing results across relevant studies. Article selection was based on journal quality and publisher reputation, ensuring that the research findings are scientifically sound and make significant contributions to the field of ICT-based learning studies.

RESULT AND DISCUSSION

RESULT

The Application of Technology in 21st-Century Learning Systems

The implementation of Information and Communication Technology (ICT) in 21st-century education has become a key driver of transformation in teaching and learning methods. Technology, particularly through online learning platforms and educational applications, facilitates more flexible interactions between students and educators. It has brought education closer to the concept of student-centred learning, in which students have greater control over selecting learning media that align with their needs (Haleem et al., 2022). This also facilitates more interactive and personalised learning, providing students with greater opportunities to learn at their own pace and in their preferred style.

Moreover, the blended learning approach, which combines face-to-face and online learning, has become increasingly popular. Blended learning enhances student engagement, as students can utilise time outside the classroom to explore the material using technology (De Bruijn-Smolders & Prinsen, 2024). This technology enables more flexible learning, allowing students to access materials anytime and anywhere. However, despite the numerous advantages, the implementation of ICT does not always run smoothly, especially in schools with insufficient infrastructure.

The use of ICT in several developing countries remains limited to simple multimedia and PowerPoint-based presentations (Abdulrahman et al., 2020; Mensah et al., 2023). This limitation is caused by the low accessibility of available technology in certain regions. This creates disparities

in the implementation of ICT in different areas. Countries with better technological infrastructure can easily integrate ICT on a broader scale. At the same time, in other regions, limited access to the internet and devices hinders the effectiveness of ICT-based learning.

Although technology can enhance the learning experience, it must be used intelligently and strategically within the context of education (Sosa-Díaz et al., 2022). Technology should serve not only as a tool for delivering content but also as a platform that enables students to interact, collaborate, and be creative. Therefore, educational institutions must design ICT-based learning systems that consider factors such as accessibility, teachers' capabilities, and adequate infrastructure.

Development of 4C Competencies through ICT-Based Learning

Kompetensi 4C (critical thinking, creativity, collaboration, communication) menjadi dasar dalam pendidikan abad ke-21. Pembelajaran berbasis TIK memungkinkan pengembangan keempat kompetensi tersebut melalui media digital yang interaktif dan kolaboratif. The use of technology in learning can facilitate critical thinking by providing students with access to a wide range of information and resources that require in-depth analysis (Taqwa et al., 2025). For example, students can explore specific topics through online discussions or web-based case analyses that stimulate critical thinking.

Creativity can be fostered by utilising design applications and digital creativity tools such as Photoshop, Canva, or Padlet, which enable students to create creative visual and multimedia works (Gurning et al., 2024; Tong, 2024). Students can collaborate on projects with their classmates through collaborative platforms such as Google Docs or Microsoft Teams, which facilitate teamwork even when separated by space and time. This strengthens the collaboration skills that are highly sought after in the global workforce.

Moreover, communication has become more effective through technology-based tools. Social media, online forums, and other communication tools enhance students' ability to communicate both verbally and in writing (Md Yunus et al., 2019). However, the development of verbal communication competencies still faces challenges, as most interactions occur in text on online platforms. Therefore, it is important to integrate more direct speaking activities in ICT-based learning to strengthen students' oral communication skills.

However, despite numerous studies supporting the benefits of ICT in the development of the 4Cs, the following opinion reveals that some students experience difficulties in adapting to technology, particularly in terms of creativity and effective collaboration (Guo et al., 2025; Wang & Raman, 2025). Another main challenge is teachers' lack of preparedness to use technology to

support the development of 4C skills, which requires ongoing training and a more structured approach to integrating ICT in the classroom.

The Barriers and Challenges in the Implementation of ICT in Education

Despite the numerous potential benefits offered by ICT-based learning, its effective implementation still faces various obstacles and challenges. One of the main barriers is limited infrastructure, particularly in areas with inadequate internet access. While devices such as tablets and computers are increasingly available, without stable internet access, ICT-based learning cannot be effectively carried out (Timotheou et al., 2023). This has led to disparities between schools in urban areas and those in remote regions.

On the other hand, teachers' unpreparedness in using technology also poses a significant issue. Many teachers still rely on conventional teaching methods due to limited skills in utilising technology (Pablos et al., 2022). Teachers who are not trained in using online learning platforms and digital tools often find it difficult to design effective ICT-based learning. This highlights the need for continuous training programs and professional development to support the successful implementation of ICT in the classroom.

Furthermore, the mismatch between available technology and educational needs also presents a barrier. Many applications and devices used in the classroom do not fully align with the learning objectives intended to be achieved (Yeung et al., 2021). The use of irrelevant applications can reduce learning effectiveness and waste resources. Therefore, it is crucial to assess educational needs and select technologies that are truly aligned with the learning objectives.

Finally, the digital divide also significantly hinders the implementation of ICT in education. Technology continues to advance, yet many students still lack adequate devices or do not know how to use them effectively (Ndibalema, 2025). Therefore, more equitable access to technology devices and training for both students and teachers is essential to address these challenges.

The Impact of ICT Learning on Student Learning Outcomes

The use of ICT in education has been shown to impact student learning outcomes positively. The integration of technology enables students to access learning materials more easily, collaborate with peers, and deepen their understanding through digital resources (Wastira et al., 2025). In this case, technology serves as a tool that enhances student interactivity and motivation, ultimately improving their learning outcomes.

A digital learning platform that provides learning analytics can offer real-time feedback to students and instructors (Topali et al., 2023). This allows students to identify their learning

strengths and weaknesses and address them before the final evaluation. This enhances learning effectiveness and accelerates the achievement of the expected competencies.

The positive impact of technology on learning outcomes greatly depends on how technology is utilised and the quality of the material being taught (Malik Nur et al., 2026). The use of technology limited to delivering content without active student interaction can reduce its effectiveness. Therefore, ICT-based teaching should be complemented by a sound pedagogical approach to maximise technology's potential to enhance student learning outcomes.

Based on these findings, ICT-based learning not only relies on tools and technological devices but also must consider the quality of interaction between teachers and students (Kurra et al., 2025). Technology should be used to support educational goals, not replace them. With the right approach, the use of ICT can have a significant positive impact on students' learning outcomes.

DISCUSSION

Application of Technology in 21st Century Learning Systems

The implementation of Information and Communication Technology (ICT) in 21st-century education has transformed the way students and teachers interact. With technological advancements, learning is no longer limited to face-to-face classrooms but can take place anywhere and anytime. Technology should be used to create student-centred learning, giving them the freedom to choose learning tools that align with their learning styles (Schmid et al., 2022). One widely implemented method is blended learning, which combines online and face-to-face instruction, offering flexibility and enhancing student engagement.

However, despite the numerous benefits of technology, a major challenge in its implementation is the limited infrastructure in many schools, particularly in areas with restricted access. Issues such as limited internet access and inadequate devices often hinder the effective integration of technology (Timotheou et al., 2023). This creates a gap in the implementation of ICT-based learning, especially between schools with comprehensive technological facilities and those without. Therefore, educational institutions must consider infrastructure-related solutions to ensure technology is used optimally.

Development of 4C Competencies through ICT-Based Learning

The 4C competencies—critical thinking, creativity, collaboration, and communication—are essential skills that students must master in the 21st century. ICT-based learning plays a crucial role in developing these competencies, particularly by providing students with access to a wide range of resources and tools to enhance their analytical and creative abilities. Technology fosters

the development of critical thinking by offering diverse information that requires in-depth analysis (Fitriani & Prodjosantoso, 2024). Students can engage in online discussions, case analyses, and technology-based projects that encourage them to think critically and find creative solutions to existing problems.

Moreover, ICT facilitates collaboration by enabling students to work together on projects or assignments through collaborative platforms such as Google Docs and Microsoft Teams. Social media and other communication apps further strengthen students' ability to communicate both verbally and in writing (Md Yunus et al., 2019). However, while technology can enhance written communication, challenges remain in developing verbal communication skills. Therefore, it is essential to integrate applications or video sessions that allow students to practice speaking and interact directly to address this challenge.

Barriers and Challenges in the Implementation of ICT in Education

Although the implementation of ICT in education offers numerous opportunities, its execution is not without barriers and challenges that need to be addressed. One of the major obstacles is the limited infrastructure in many regions, especially in developing countries. While technological devices such as laptops and tablets are becoming more accessible, unstable or limited internet access hinders the optimal use of technology in learning (Timotheou et al., 2023). This limitation exacerbates the gap between regions with comprehensive facilities and those with less supportive ones, preventing students in certain areas from fully benefiting from ICT-based learning.

In addition, the lack of readiness among educators to use technology also presents a significant challenge in the implementation of ICT. Many teachers do not possess sufficient skills to integrate technology into their teaching (Akram et al., 2022). Many educators still rely on conventional methods due to the lack of adequate training in utilising digital tools. To address this issue, it is crucial to provide ongoing training for teachers so they can use technology effectively in line with the desired learning objectives.

The Impact of ICT Learning on Student Learning Outcomes

The integration of Information and Communication Technology (ICT) in education has been shown to impact student learning outcomes positively. Technology allows students to learn more flexibly by accessing materials anytime and anywhere (Najjar et al., 2025). This enhances student motivation, as they feel they have more control over their learning process. The use of digital learning platforms equipped with learning analytics enables instructors to provide real-time feedback, helping students to address their weaknesses before the final evaluation (Ifenthaler et

al., 2023). Therefore, technology not only improves access to materials but also accelerates the attainment of the expected competencies.

However, these positive impacts depend heavily on how technology is implemented in the classroom. If technology is used merely as a tool for delivering content without active interaction between the instructor and students, its benefits will be limited (Valverde-Berrocoso et al., 2022). Thus, ICT-based teaching must be supported by pedagogical approaches that facilitate active student engagement, such as discussions, collaborative projects, and technology-based assignments that encourage creativity and critical thinking skills. With proper integration, ICT can significantly enhance student learning outcomes.

CONCLUSION

The implementation of Information and Communication Technology (ICT) in 21st-century education has brought significant changes, both in the development of 4C competencies and in the improvement of student learning outcomes. Despite the many potential benefits, such as increased student engagement, creativity, and collaboration, the main challenges remain the limitations of infrastructure and teachers' preparedness to use technology effectively. Therefore, to achieve more effective learning, educational institutions need to address these barriers through continuous teacher training and improved access to technology. The prospects of this research offer opportunities to develop a more inclusive ICT-based learning model that also takes into account the local context and students' digital readiness by fully integrating technology into an adaptive, data-driven learning design.

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