IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 3 July 2023, accepted 14 August 2023, date of publication 18 August 2023, date of current version 29 August 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3306603

TOPICAL REVIEW

Digital Transformation in Secondary Schools: A Systematic Literature Review

TANTI MEISHANTI YULIANDARI, ATINA PUTRI, AND YUSEP ROSMANSYAH
School of Electrical Engineering and Informatics, Bandung Institute of Technology, Bandung 40132, Indonesia
Corresponding author: Tanti Meishanti Yuliandari (23221017@std.stei.itb.ac.id)

This work was supported by the School of Electrical Engineering and Informatics, Bandung Institute of Technology (ITB).

ABSTRACT As the educational landscape changes rapidly, secondary schools increasingly adopt digital technologies to transform teaching and learning experiences. Recognizing the challenges and potential advantages that arise in the digital era, educators are actively undertaking digital transformation initiatives across various domains, with secondary schools being the key focus of this paper. To clarify the matter, four research questions were formulated in this systematic literature review: 1) What is the state-of-the-art for digital transformation research in secondary schools? 2) What are the essential indicators for conducting digital transformation in secondary schools, as identified by researchers? 3) What are the models or frameworks for digital transformation in secondary schools? 4) How to implement digital transformation in secondary schools? A formal protocol was followed to conduct automatic and manual searches of relevant articles published between January 2012 to March 2023 using the PSALSAR method. As a result, 65 papers were selected for review. This study highlighted six key factors successfully implemented in digital transformation: leadership, digital competency, professional development, technology access, school evaluation, and school competency. Furthermore, the study discussed current research trends, methods, and strategies to develop standard models and frameworks related to digital transformation in secondary schools. Challenges and potential areas for further development were investigated to facilitate a successful digital transformation.

INDEX TERMS Systematic literature review, digital transformation, secondary schools, digitalization.

I. INTRODUCTION

Digital transformation is the management of processes, people, and technology that aims to efficiently carry out all business activities to meet the needs and expectations of society interested in adapting to Industry 4.0 [1]. Digital transformation goes beyond the digitization process to radically change actions, strategies, capabilities, and organizational patterns to meet the challenges and take advantage of the opportunities of new technologies and their accelerated impact on society. Digital transformation leverages technological resources, primarily digitizing, storing, retrieving, and communicating data, to reposition business processes [2]. The objective of digital transformation in education is to realize a comprehensive vision that facilitates ongoing innovation and advancement in teaching and learning, concurrently streamlining administrative and management services for students, educators, and the community to enhance operational efficiencies [3].

The primary and secondary education systems are responsible for educating upcoming global citizens and workforces, particularly in employment disruption and increased polarization. Educational approaches must transform to equip students with the necessary knowledge and skills to foster a more inclusive, cohesive, and dynamic society [4]. Digital technologies are leveraged to mitigate significant data gaps at both global and national levels. They facilitate the generation of real-time information and predictive analytics, enhancing the integration of decision-making processes and prioritization. Moreover, these technologies enable valuable feedback

The associate editor coordinating the review of this manuscript and approving it for publication was Rebecca Strachan.

on the efficacy of policies, thereby fostering continuous improvement and optimization [5].

Traditional classroom education provides an immediate learning environment, quicker assessment, and more engagement. On the other hand, digital learning tools and technology fill in these gaps. The efficiency provided by technology is unparalleled by traditional learning methods. Utilizing smartphones and other wireless devices is becoming more popular among the public. It is a rational action for schools and educational institutions to use technology in the classroom learning process efficiently. Current technology's adaptability and non-invasive nature make learning more enjoyable and engaging for the millennial generation [6]. Thus, the smart learning environment (SLE) is a combined educational system incorporating intelligent tools and techniques to create a delightful learning experience for learners and other individuals involved. The ultimate goal of SLE is to achieve desired learning outcomes [7]. Additionally, smart learning encompasses various aspects of the learning environment, including infrastructure, technological devices, pedagogical approaches, and learners' profiles, to utilize intelligent devices efficiently. In Korea, smart learning is regarded as a learning paradigm that prioritizes human interaction and content rather than devices. It also emphasizes the importance of effective, intelligent, tailored learning supported by advanced IT infrastructure, as recognized by the government, academia, and the educational industry [8].

Learning technology today plays a crucial role in the education system, providing opportunities for educators to enhance education and improve student's overall performance. Information dan Communication Technologies (ICT) use in education is not limited to knowledge transfer from teachers to students. Moreover, it also enables real-time sharing of learning activities through networks. The convergence of ICT in education enhances restructuring, and creates new opportunities for more meaningful, comprehensive learning, and improving overall teaching and learning skills [9]. The e-learning platform is utilized to enhance student's learning experience and provide opportunities for educators to expand their technical and academic skills, enabling them to compete with other skilled and high-quality teachers. Despite numerous advantages, the e-learning platform has limitations, such as insufficient support and guidance and virtual guidance for personalized options modified to individual needs [10].

The potential of digital transformation in schools and other educational entities increasingly recognize has yet to be fully utilized, hence the importance of improving efficiency and collaboration to reduce costs and errors in management. Digital transformation can begin with the utilization of technological opportunities and the fulfillment of stakeholder system goals [11]. The previous study stated that e-tutoring programs should be incorporated into educational systems worldwide to accelerate digital transformation. A remote learning program called e-tutoring supports students' learning using digital tools. A teacher or tutor helps students clarify concepts, gain knowledge, develop skills, and change their attitudes toward the subject. In contrast, one or more students generally seek access to knowledge or support/clarification on a specific learning need. It is an innovative teaching practice. The objective is to foster collaboration between students and teachers, transcending the boundaries of their compulsory educational curriculum. The tools for student engagement in the e-tutoring program are user-friendly and readily available. Participants must have access to internet connectivity, a computer, tablet, or mobile phone, along with a designated link [12].

The study of educational system transformation presents challenges in the digital era, necessitating the preparation of graduates with the required competencies to keep up with the rapidly changing world. Furthermore, digital transformation must be directed, carefully considered, and systematically managed. Thus, awareness of the primary objectives of modern education, the establishment of a digital school vision, and consistent implementation are required. Digital transformation in secondary schools is accomplished by implementing innovative education in national projects that refer to the education and school transformation for the digital era, especially for school management and coordinators. The SELFIE tool is employed to evaluate the current digitalization condition from the perspectives of students, teachers, and leaders to prepare action plans for transformation. The results indicate that the essential features of digital schools are the creation of a digital school vision, updating the vision and action plan, teacher's digital competency, student preparation for practice, and constructivist approaches to education. In digital transformation, the role and support of leaders managing school transformation are crucial in directing transformation at the national level [13]. Transformation at the national level involves testing school principal's perceptions in keeping up with the new digital era trend and assessing their knowledge and ICT skills. Additionally, it investigates their willingness to respond to the demands and challenges of the education system that is compatible with the digital era while ensuring the function of schools as learning organizations. This questionnaire-based research found that school principals have had a positive view and attitude towards digital platforms available in education over the past two years, despite many of them having low ICT skills and knowledge. The transformation of digital education is a slow process due to various obstacles that hinder the transformation of academic units into learning organizations [14].

Based on the background mentioned earlier, this study aims to deepen the understanding of secondary school's current digital transformation research. SLR identifies research gaps in a field of study and helps researchers further explore areas that have not been explored before. The SLR technique is combined with bibliometric analysis to identify the state-of-the-art for current research, used comprehensively and collectively to review a field of study and help identify

intellectual structures [15]. Therefore, a systematic literature review is needed to understand current research trends, identify important indicators, including standard models or frameworks, and identify ways to implement digital transformation in high schools.

II. RESEARCH METHODOLOGY

Systematic Literature Review (SLR) is a method used to synthesize scientific evidence to answer specific research questions that are clear and reproducible. Moreover, this method strives to include all published scientific evidence on the topic being researched and assesses the quality of that scientific evidence [16]. The methodology used to minimize potential subjectivity, the literature review, and the analysis elements were based on the SALSA Framework. The SALSA methodology is one of the most appropriate tools for identifying, evaluating, and organizing literature, ensuring methodological accuracy and completeness of the literature review. In addition, the PRISMA method was followed to ensure the completeness and consistency of the research process [17]. The SALSA Framework has four basic steps, including search (determining search strings and types of databases), appraisal (inclusion and exclusion of pre-determined literature and quality assessment criteria), synthesis (extracting and categorizing data), and analysis (analyzing the results to reach conclusions). This paper adds two steps: protocol (determining the scope of the research) and reporting results (stating the procedures followed and communicating the results to the public). The result has six steps, abbreviated as PSALSAR (protocol, search, appraisal, synthesis, analysis, and report) [18].

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a set of evidence-based minimum items for reporting in systematic reviews and meta-analyses. PRISMA focuses on reporting studies that assess the impact of interventions but can also be used as a basis for writing systematic reviews for purposes other than determining interventions. It is designed to help systematic reviews report transparently why the study was conducted, what the authors did, and what they found. Advances in systematic review methodology and terminology have led to updates for guidance [19]. In this study, PRISMA is employed as a visual representation tool, specifically as a flow diagram that illustrates the progression of information during the various stages of a systematic review. It visually represents the quantities of records identified, included, excluded and the reasons for exclusions.

The PSALSAR framework continues the search phase after the research protocol is established. This step involves searching databases for pre-selected keywords. Selecting the appropriate databases is important to ensure the research is high quality, reliable, and representative of the desired topic. The main purpose of scientific publications is to facilitate the exchange of research results, ideas, and discussions globally among academic community members so that scientific achievements can be more efficient. However, over time, the role of scientific publications has undergone significant changes, with many important decisions in industry and economics, such as growth priorities, allocation of funding sources, educational policies, collaboration opportunities, tenure, and academic staff recruitment, depending on assessments of scientific output. The quality of research is considered an impact of publication and is used as the most important criterion. Therefore, a digital library that provides publication metadata and impact indicators is needed. Thus, they function as the main tool for various tasks ranging from journal selection, large-scale literature analysis, and research evaluation practices at all levels, allowing for efficient and accurate research reviews [20]. WoS is often called the most reliable independent global citation database. WoS is a data source produced by Clarivate Analytics, while Scopus is a data source created by Elsevier. Different data sources have different content selection policies. WoS has an internal editorial team to select content. WoS emphasizes selectivity in content selection, while Scopus works with an international group of researchers known as the Content Selection and Advisory Board to make content selections. Scopus focuses more on completeness than selectivity, as it often emphasizes database size compared to WoS [21].

Since Google Scholar's launch in November 2004, Google Scholar has brought Google's search convenience to academics and changed how people search, discover, and access academic information. Before Google Scholar, the coverage of academic databases was limited to a list of selected sources, especially scientific journals. However, Google Scholar is automated by crawling the web and indexing documents with an academic structure. This inclusive approach gives Google Scholar the potential for wider coverage of scientific and academic literature compared to the two other major multidisciplinary databases, Web of Science (WoS) and Scopus, which select sources based on selective journal inclusion policies [22]. The authors searched digital libraries such as ACM Digital Library, IEEE Xplore, Frontiers, Science Direct, Springer Link, and Taylor & Francis to enhance the literature search's comprehensiveness. The resulting dataset underwent a systematic literature review analysis using both quantitative and qualitative methods. The quantitative method involved objective theory testing by examining the relationships between variables. Variables were typically measurable and calculable through instruments, enabling numerical data analysis utilizing statistical techniques. It examines the objective theory. Quantitative research involves analyzing the relationship between measurable variables using instruments to generate numerical data that could undergo statistical analysis. This method also assumes deductive testing of the theory, constructing protection against bias, controlling alternative or counterfactual explanations, and being capable of generalizing and replicating findings [23]. The PSALSAR method utilized in this study is a straightforward, transferable, and reproducible procedure for conducting a systematic literature review. Its detailed implementation steps are described in Table 1.

TABLE 1. PSALSAR framework phases.

Phases	Main Task	Outcomes
Protocol	Determine the research scope	Indicators in determining the keyword search strategy using PICOT (population, intervention, comparison, outcome, and time).
Search	Searching for research article Study selection	The inclusion and exclusion criteria are based on the PRISMA statement.
Appraisal	Research quality assessment	Quality assessment checklist.
Synthesis	Data extraction Categorizing Data Data analysis	Constructing templates for data extraction. Organizing data for further analysis. Categorizing quantitative and qualitative data through a descriptive and narrative analysis of organized data.
Analysis	Discussion and result	Summary of research conclusion and recommendation.
Report	Making a report	Summary of research conclusion and recommendation.

A. PROTOCOL

In the context of a systematic literature review, a research protocol is required to consider factors such as the work's transparency, transferability, and replicability. It helps to reduce bias by conducting a thorough literature search. However, the main challenge in this stage is determining the appropriate scope of the research [18].

An SLR aims to interpret conflicting results from primary studies, summarize the findings of many primary studies, and assess the application of external evidence, especially when only a few primary studies are available. Reproducible results are another important benefit of a systematic review due to its openness and methodological clarity. A systematic review helps identify the research quality on a targeted topic to avoid duplication by screening documents and providing insights through comparison or combination of different studies [24]. An SLR on digital transformation in secondary schools as a case study is presented in the form of research questions as follows:

RQ 1. What is the state-of-the-art for digital transformation research in secondary schools?

RQ 2. What are the essential indicators for conducting digital transformation in secondary schools as identified by researchers?

RQ 3. What are the models or frameworks for digital transformation in secondary schools?

RQ 4. How to implement digital transformation in secondary schools?

The PICOT (population, intervention, comparison, outcome, time) method plays a role in developing research questions or hypotheses to determine the appropriate scope of research. PICOT is a process that drives literature review and can be transformed into research questions or hypotheses following the results of the literature review that has been conducted. Several gaps and consistencies can be identified during the literature review so that research questions or hypotheses can be formulated to enhance understanding of the topic being studied to a higher level [25]. PICOT is added in the PSALSAR Framework stage to ensure transparency and the ability to transfer knowledge from a study. PICOT provides a predetermined decomposition structure required for research questions and improves the definition of the research scope. PICOT questions aim to identify terms that will be used as the best search strategy in answering questions scientifically to avoid bias and ensure effectiveness. Unbiased and effective searches lead to evidence. Therefore, evidence will answer questions, and support recommendations, decisions, and evidence-based practices [26].

This study selected keywords based on PICOT to address the research question. However, some criteria, namely comparison, and outcome, as demonstrated in Table 2, could not be met due to the scarcity of studies on digital transformation, particularly in the school setting. In this regard, the comparison criterion was not utilized as the study did not involve a comparison between different methods. Moreover, the outcome criterion should have been incorporated in the search as it is the primary focus of the study.

TABLE 2. PICOT method.

Component	Scope Study
Population	Secondary School
Intervention	Digital Transformation
Comparison	Data extraction Categorizing data Data analysis
Outcome	Discussion and result
Time	2012-2023

B. SEARCH

The search stage involves a keyword search strategy. The search strategy helps determine the appropriate search string and identify relevant databases to gather appropriate documentation to answer the research question. A literature search is conducted from popular digital libraries in the field to search for a wide range of literature studies. The digital libraries used in the study are as follows:

1. Google Scholar (scholar.google.com)
2. Scopus (scopus.com)
3. Web of Science (wos-journal.com)
4. ACM Digital Library (dl.acm.org)
5. IEEE Xplore (ieeexplore.ieee.org)
6. Frontiers (frontiersin.org)
7. Science Direct (sciencedirect.com)
8. Springer Link (springerlink.com)
9. Taylor & Francis (tandfonline.com)

From those databases, the search strategy for conducting SLR analysis can be determined. However, the number of databases is significantly limited by the search strings used, with the number of publications in each database limited from January 1st, 2012, to March 31st, 2023.

The search string based on the PICOT method outlined in Table 2 was used to answer the research question. The authors considered the following search: (digitalization OR transform* OR "digital transformation" OR "transformation digital") AND (school* OR "high school" OR "secondary school" OR "middle school"). Search terms were used individually or in limited combinations, considering the needs and limitations of the databases used. The databases used in this study were Google Scholar, Scopus and WoS, IEEE Xplore, Science Direct, Frontiers, Springer Link, and Taylor & Francis. According to the PICOT search strategy, articles were obtained from journal papers from eight databases with a literature search limit.

C. APPRAISAL

The appraisal stage involves selecting and evaluating articles based on an objective review. The purpose of selecting studies requires an examination of the selected literature to identify relevant studies for review.

1) SELECTION OF RELEVANT STUDIES

Selection of relevant studies involves two basic steps: selecting studies based on quality assessment, inclusion, and exclusion criteria. Table 3 describes the inclusion and exclusion criteria in the study.

TABLE 3. Inclusion and exclusion criteria.

Type of Criteria		Criteria
Inclusion Criteria	IN1	Index terms is digital transformation in secondary school
	IN2	Written language in English
	IN3	Type of documents (journal)
	IN4	Full text articles
	IN5	Grade level only in secondary schools (secondary school, middle school, high school, and vocational high school)
	IN6	Publication year during period 2012-2023
Exclusion Criteria	EX1	Articles does not relevance to digital transformation in secondary schools
	EX2	Written in other languages than English
	EX3	Types of documents (conference papers, books, book review, book chapters, note, editorial, conference review, erratum, short survey, letter, magazines)
	EX4	Publication year before 2012 and after 2023
	EX5	Could not full access to journal source

An explanation of the process for selecting articles is shown in Figure 1. Figure 1 shows the identification process of the study through databases and registers automatically, explaining the literature selection procedure for the PRISMA flow diagram in conducting SLR analysis. The process started with an initial search, obtained through an automated search by applying exclusion criteria, 980 articles related to the Google Scholar database were obtained, along with 1,305 articles from Scopus and 1,283 articles from WoS. After applying exclusion criteria by limiting the publication years from January 1, 2012, to March 31, 2023, a total of 1,474 articles were removed. Subsequently, 53 articles not in English and 21 that needed journal-type documents were excluded. Additionally, 24 articles were inaccessible due to limited access rights. Consequently, after applying the exclusion criteria, a total of 1,996 articles remained for further formal screening.

On the other hand, as most of the articles from the three databases were less relevant to the main topic, mainly focusing on higher education, primary education, transformational leadership, and general education without any application of technology, the authors added some literature from ACM Digital Library, IEEE Xplore, Frontiers, Science Direct, Springer Link, and Taylor & Francis to widen the scope of the digital transformation research in secondary schools. Therefore, the manual search strategy was carried out to complete the relevant articles on the ACM Digital Library database, which generated 18 articles, 14 articles for IEEE Xplore, 19 articles for Frontiers, 15 articles for Science Direct, 33 articles for Springer Link, and 15 articles for Taylor & Francis. A manual search yielded 114 articles for further formal screening. Then combined, the result in a total of 2,110 articles will be further selected based on the quality assessment criteria. After that, 1,516 duplicate articles were automatically removed using Zotero tools after a duplication check, leaving 594 articles for further screening. In addition, 594 articles were manually screened by reading relevant titles and abstracts related to the topic of digital transformation in secondary schools. Then, 277 articles were found irrelevant to digital transformation. Among the 317 articles considered relevant, the authors checked for full-reading papers. Furthermore, 252 articles were found, but it belongs to something other than the secondary school level. Finally, after following the PRISMA flow, 65 relevant articles were obtained on the main topic.

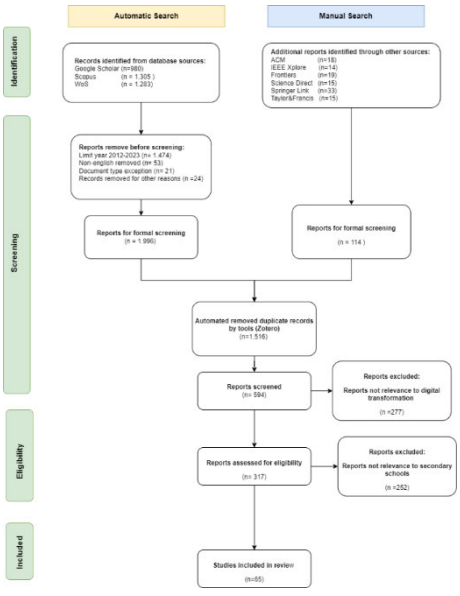

FIGURE 1. Flow of selected articles based on PRISMA.

2) QUALITY ASSESSMENT

The quality assessment phase helps to check, evaluate the accuracy, and the reliability of the selected articles based on a quality assessment that describes the value according to the quality level of the article. Referring to the literature [18], each article selected for SLR analysis was evaluated using the questions used as evaluation criteria as follows:

- Does the paper clearly state the purpose of the research?
- Is the research question or hypothesis clearly defined?
- Are the methods used in the study appropriate to answer the research question?
- Does the paper identify gaps in the previous research that the current study aims to address?
- Are the results of the analysis clearly presented and explained?
- Does the paper clearly present the main findings of the study?
- Does the study contribute to the existing knowledge that is relevant to the topic?
- Does the paper discuss the limitations of the study?

Table 4 represents the quality assessment of the selected articles in the systematic literature review.

TABLE 4. Quality assessment checklist.

Category	Description	Score
Yes	The information is provided clear explicitly	1
Partially	The information is provided clear implicitly	0.5
No	Information cannot be inferred	0

Source: Modified by authors using [27]

Table 5 presents a detailed description of the selected articles based on the relevant databases. After a full reading of the 65 articles, it was found that 41 articles explicitly provide clear information about digital transformation. In comparison, 24 articles offer implicit information that requires further interpretation or analysis for a correct understanding. Only a portion of the information provided by these articles can be considered meaningful in answering the research questions.

TABLE 5. Selected articles.

Digital Library	Article
Google Scholar	11
Scopus	11
WoS	1
ACM Digital Library	1
IEEE Xplore	7
Frontiers	4
Science Direct	6
Springer Link	16
Taylor & Francis	8
Total	**65**

D. SYNTHESIS

In the synthesis phase, extracting and classifying relevant data from selected publications was carried out to gain insights and draw conclusions. The synthesis stage was performed on 65 articles analyzed through SLR. Table 6 describes the classification of information from acronyms based on the results of full-reading papers to facilitate the authors in answering research questions.

TABLE 6. Topic information classified.

Topic	References
Actors or stakeholders involved in DT	[13], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48].
DT description	[11], [34], [49], [50], [45], [51], [44].
DT implementing methods	[11], [12], [8], [52], [53], [54], [55], [56].
DT governance	[39], [45], [50], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67].
DT leadership	[40], [41], [42], [43], [44], [45], [46], [47], [48], [49].
Technologies used	[38], [39], [59], [46], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [51], [87], [88].

Source: modified by authors using [27]

E. ANALYSIS

The analysis phase involves assessing the synthesized data, extracting important information, and drawing conclusions from the selected articles to answer the research questions. Based on the data analysis results from the selected articles, the authors gained insights into the definitions related to digital transformation in secondary schools, which are presented in Table 7.

Figure 2 explains the articles discussing actors' direct involvement in the digital transformation process at secondary schools. 37% of the articles describe the role of school leaders in driving school leadership practices to shape digitally based schools. It is recognized that principals, as the decision-makers in the education system, surpass the implementation of isolated digital innovations and instead adopt a transformative mindset, utilizing technology as an enabling tool. Then, it was observed that 25% of the articles talking about actors or stakeholders involved in DT considered were teachers. The articles define teachers' need to possess proficient digital competencies skills when utilizing digital resources that facilitate the development of innovative and creative instructional methods.

Meanwhile, 18% of the articles discuss students and the factors considered, including students' availability of learning devices, their level of digital skills preparedness, their familiarity with online learning and assessment activities, and their comprehensive assessment of the efficacy of online learning. Approximately 18% of the articles discuss the idea policy makers should recognize the contextual aspects involved in governance by balancing the ability to

TABLE 7. Definitions related to digital transformation in secondary school.

Reference	Definition
[34]	Digital transformation triggers substantial and intricate changes in the school sector, encompassing more than technical factors like digital infrastructure and classroom equipment. They include digital school organization, curriculum adjustments, new competency standards for school management and teachers, and a comprehensive adaptation of school culture.
[49]	Digital transformation is an iterative process that responds to new digital innovation's rapid and continuous emergence. This process necessitates agility and needs a well-defined endpoint, limiting any exhaustive review's extent. Although digital transformation is often regarded as a keyword that relates mainly to large organizations utilizing technology to enhance outcomes, there is a common misconception that technology is the primary driver of change. Instead, technology functions as a supporting element for change and is regarded as an enabler of transformation. Defining the term digital transformation for school leaders provides a foundation to construct a shared vision and highlight that digital transformation encompasses more than merely technological innovation.
[11]	The digital transformation began with an articulated strategy that capitalized on the advantages of emerging technologies while concurrently fulfilling the requirements of the stakeholder's system. This strategy was iteratively developed for the education sector, facilitating connectivity across all aspects of the system to support the demands of the digital world of the future. Strategic partnerships were forged to establish an ecosystem that effectively linked people, processes, and things, creating a robust, secure, and intelligent communications network.
[50]	Digital transformation is an improvement of elements related to the strengths and weaknesses of school management in achieving goals, depending on the school's strategic approaches.
[45]	School's digital transformation is a top priority in education and the use of digital materials will be vital in making it successful. Both students and teachers must acquire digital skills, and the influence of school principals will be crucial in adopting and utilizing specific educational digital resources that align with learning goals. School principals have a deep understanding of the educational environment and can shape the teaching methodology by providing leadership. They can act as a cornerstone for the ongoing digital transformation by integrating high-quality digital content into education.
[51]	Digital transformation in schools is not to add more technology but to efficiently utilize existing digital resources to facilitate the desired change to achieve learning objectives.
[44]	Digital transformation in schools requires more than technological integration. It encompasses educational curricula, teaching, and learning culture changes to prepare future generations for diverse job markets and societies. The goal is to address broader societal digital transformation challenges and foster digital literacy and 21st-century skills.

translate policies with the consistency of those translations. It is essential to consider the significance of strategic and operational policy coherence. The primary objective of this study is to address the development of a national action plan for the digitalization of schools. For each 2% of the articles narrate about involvement, the members of the school management, block education mentors, and the pedagogical center coordinators actively position themselves throughout the digital transformation process, considering different aspects. They aim to identify potential improvement areas and generate practical, evidence-based recommendations.

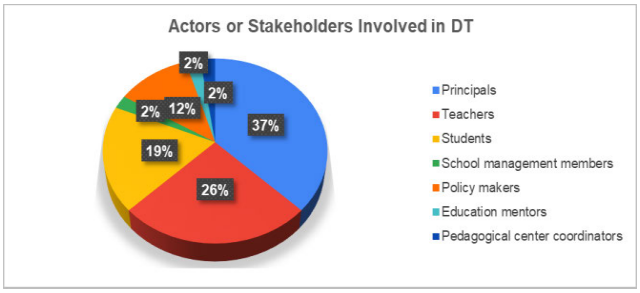

FIGURE 2. Actors or stakeholders involved in DT at secondary schools.

After engaging with actors or stakeholders involved in digital transformation, we discovered various methods for implementing digital transformation. The study explains establishing a center of competencies, which consists of conducting regular project activity assessments to generate reports. Secondly, it ensures that the implementation aligns with the planned objectives. Thirdly, it identifies the changes and assesses the impact on teachers' and students' skills. This work also discusses the evaluation framework, presenting findings on feedback, follow-up, and observed effects gathered from the field. The evaluation emphasized that the labs successfully enhanced teachers' competence and highlighted the benefits of cascade training, which disseminated digital knowledge and awareness among the participating schools [11]. Developing and operating a system, such as e-tutoring sessions for high school students, as an expansion of their school's e-learning activities, while meeting the expectations of the users to create smart learning environment [8], [12], [54], [55]. Another method is digitalization with the process of digitalizing schools entails inherent challenges. The decision has been made to incorporate an IT-supported approach for teaching literacy. The profound integration of digital technologies within pedagogy and learning brings about significant modifications in classroom roles, relationships, and actions, which can potentially disrupt established teacher routines [52], [53]. For further information analysis, a more in-depth discussion will be conducted to address the research questions in the report phase.

F. REPORT

The reporting phase of the SLR includes an explanation of the methods used and the results obtained from the selected literature review. The reporting phase consists of two steps [18]:

1. An explanation of the main procedures used which are described in Table 1.
2. Presentation of publication results such as journal articles. In SLR, making journal articles is the last stage and helps produce research outputs useful to the scientific world.

1) RQ 1. WHAT IS THE STATE-OF-THE-ART FOR DIGITAL TRANSFORMATION RESEARCH IN SECONDARY SCHOOLS?

The state-of-the-art explores important aspects that shape the historical development of a topic, factors influencing changes in understanding, and ways of thinking and learning about the topic that can lead to new insights in the future [89]. Figure 3 shows the distribution of selected literature trends based on the year of publication, from January 2012 to March 2023. Two related studies were found in 2012, but no articles were found on the searched topic in 2013 and 2016. In 2014 and 2015, one literature study was selected each year, while three articles were selected in 2017 and five articles in 2018. There was a significant increase in 2020 with nine articles, a peak in 2021 with 19 articles, and decrease in 2022 to 16 articles. Three relevant articles were selected from the year 2023, as of March 31st. The small number of articles in the year 2023 is due to the fact that it covers only three months instead of the entire year.

Therefore, based on the research trend shown in Figure 3, it is premature to conclude that interest in the digital transformation of secondary schools is decreasing. Rather, interest in this field has grown and evolved in recent years, highlighting the need for digital transformation research, especially in secondary schools, where it is more than just a matter of technological innovation but a necessary solution for improving the quality of education. Digital transformation can help create an effective national digital strategy that addresses cultural, educational, and ideological challenges in government decision-making regarding information [90].

The authors further analyzed the latest topics related to digital transformation from selected literature using a VOS viewer to visualize trends based on the latest research, as shown in Figure 4. Generally, the ten terms with the highest occurrences extracted from the abstract and title of the selected literature were school, teacher, education, student, study, technology, learning, digital transformation, framework, and principal. These terms indicate that some studies discuss actors, schools, and elements involved in transformation, such as study, technology education, teacher, student, and principal. In addition, the framework used in digital transformation was also highlighted. Circles with the same colour clusters indicate publications on the same topic. In the 1st cluster marked in red, the highest occurrence terms are digital technology, learning, practice, student, teacher, teaching, etc. They relate to ''actors or stakeholders involved in DT and technologies used.''

Furthermore, the second cluster in green represents the topic of ''DT governance,'' involving terms such as digital transformation, education, framework, study, technology, etc. Then, the third cluster in blue discusses ''DT implementing method and DT description'' with terms such as digitalization, concept, change, process, school, transformation, etc. In the fourth cluster discusses ''DT leadership,'' model, principal, research, use, etc. Then the last cluster is the fifth cluster in purple colour. There is only one keyword, namely area, which is intended to describe the research topic area in the field of digital transformation, linking several other keywords such as school, education, leadership, digital technology, digital transformation, framework, student, teacher, etc.

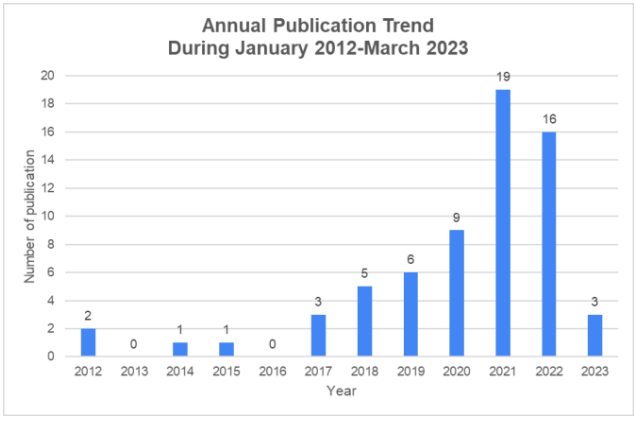

FIGURE 3. Publication trend of DT in secondary schools (January 2012-March 2023).

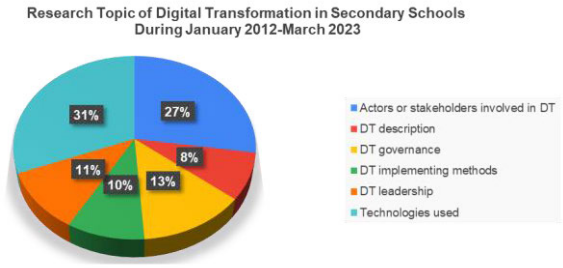

FIGURE 4. Research topic of DT in secondary schools (January 2012-March 2023).

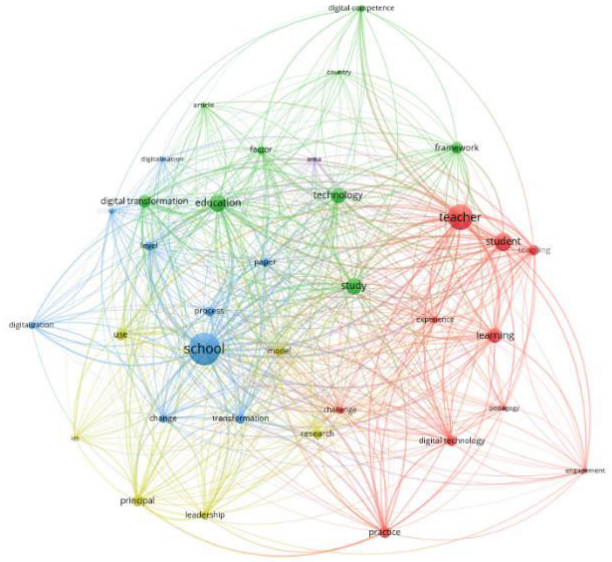

FIGURE 5. Visualization map of DT in secondary schools trending topic.

Based on the five identified clusters, it can be concluded that from 2012 to 2023, the latest research trend in the field of digital transformation in secondary schools is centered around the actors and stakeholders involved in DT, as well as the technologies used, which are the keywords with the

highest occurrence values. These results are consistent with the full reading papers described in Figure 5, where the SLR method generated a percentage value for information classification, with 31% discussing the technology used. In comparison, 27% focused on actors and stakeholders involved in DT. Furthermore, 15% discussed DT governance, 11% addressed DT implementing methods, and 9% focused on DT description.

2) RQ 2. WHAT ARE THE ESSENTIAL INDICATORS FOR CONDUCTING DIGITAL TRANSFORMATION IN SECONDARY SCHOOLS AS IDENTIFIED BY RESEARCHERS?

Based on UNESCO [91] report about guidelines for ICT in education policies and masterplans, by employing information and communication technology (ICT), teachers can introduce innovative teaching methods that make education more inclusive and better adapted to the needs of the community. Additionally, using ICT can support student success, empowering them to become engaged global citizens. The studies selected used multiple instruments to examine different aspects based on various kinds of literature to find some important indicators for conducting digital transformation. The indicators are shown in Table 8 for an overview of it.

TABLE 8. Overview of digital transformation in secondary school's indicators.

Topic	References
Digital competencies	[13], [29], [35], [36], [50], [45], [56], [60], [66], [67].
School leadership	[49], [45], [44], [40], [41], [42], [43], [46], [47], [48].
Professional development	[30], [53], [13], [64], [79].
DT governance	[38], [39], [59], [46], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [51], [87], [88].
Access to technologies	[11], [12], [31], [58], [62].
School evaluation	[36], [37], [56], [66], [59], [77].
Secondary school's policy	[13], [29], [35], [36], [50], [45], [56], [60], [66], [67].

According to the results of Table 9, one of the critical indicators is digital competencies was identified as comprising four key areas, including [36]:

1. An understanding of the impact of digitalization on society.
2. Proficiency in using and comprehending digital tools and media.
3. The adoption of a critical and responsible perspective.
4. The ability to transform ideas into actionable solutions.

Future education opportunities require two strategic priorities that reflect previous focuses on digital competence and introduce new ones. These priorities involve cultivating a high-performing digital ecosystem and enhancing digital skills and competencies to keep pace with the digital age [66].

In teacher education, the potential of new teachers to introduce contemporary ideas and perspectives to the classroom is often lost once they become entrenched in existing school norms and practices. By encouraging them to adopt a more expansive view of digital competence, they may challenge traditional thinking and become advocates for a more inclusive and contemporary approach to teaching. Typical methods for enhancing digital competence have been centered around encouraging students to accomplish their academic objectives. The previous study highlights teacher educators' challenges in developing a holistic perspective on digital competence among their students. In addition to educating their students to use current and emerging digital tools in their professional practice, teacher educators must also equip them with the skills needed to use technology in practical ways that benefit their students and enable them to use technology productively. The complexity of this task lies in developing a transformative competence in students that empowers them to use digital resources effectively in specific instructive, learning design, classroom organization, and assessment practices rather than just addressing their immediate capacity needs. However, digital literacy encompasses the proper utilization and assessment of digital resources, tools, and services and applying these skills to lifelong learning processes. Based on recent research advocates for a reevaluation of the objectives of teacher education programs, proposing that the current focus on skills-based digital literacy should be relinquished in favor of more inclusive digital competency models that acknowledge the diverse knowledge, capabilities, and attitudes required of future educators [60]. In addition, according to an academic dictionary, the definition of digital literacy from the late 20th century remains unchanged, encompassing proficiency in using computer hardware, comprehending the basics of computer science, and recognizing the significance of information technology in society. At the same time, the digital tool's environment fully integrates into the student's learning experience [86].

Digital literacy is needed compared to the widespread use of digital technology in everyday life. The integration of digital technology in teacher education and schools for teaching and learning purposes has been limited. Consequently, teachers may lack advanced technology-related teaching skills. As basic digital skills are considered the foundation for technology-related teaching skills, teachers rate them significantly more advanced than their technology-related teaching skills. Previous research has demonstrated that digital technology is extensively utilized in classrooms to support teaching. Still, teachers have yet to fully leverage their potential for engaging learners as active participants in the learning process [75]. The potential of digital resources in pedagogy has emerged as a challenge for educational processes, stimulating transformation and innovation. Despite many studies on digital education, more consensus regarding digital resources' effects on educational processes has yet to be reached. Most of the literature views technology as an opportunity to overhaul education and pedagogical processes, thereby bringing education in line with the expectations of a digital society [45].

Most educational establishments, spanning various tiers of education, traditionally employ conventional instructional techniques, primarily in-person lectures within the classroom setting. However, the recent surge in the ''digital transformation in daily life'' has resulted in the necessity to provide equivalent educational courses through online video conferencing software or dedicated distance learning platforms. This shift has markedly affected student's academic progress and aptitude [71].

Using technology to influence student's academic progress and abilities significantly necessitates assessment to evaluate school quality. The present study underscores the educational system's difficulties, such as the need for superior teaching and assessment resources, inadequate training, and student equity issues related to access, technological proficiency, support, and special-needs students. Moreover, time constraints for teachers further compound these challenges. Consequently, the education community must explore and introduce novel approaches to bolster student-student and student-teacher interaction in virtual settings, develop authentic digital evaluation instruments, and foster an all-inclusive and pertinent curriculum and pedagogy [53]. The novel assessment strategies were congruent with the instructional techniques implemented by the educators. Specifically, in the context of collaborative tasks, the instructors utilized three forms of student evaluation: peer assessment, feedback provision, and rubrics [8]. The provision of adequate resources, training, and motivation is essential for the success of both students and teachers. Educators can effectively utilize today's technologies through professional development resources with access to modern personalized learning environments and technology tools [79].

The principal's leadership is needed to support these indicators to facilitate the school's digital transformation. The responsibility of a school principal is to enable the ongoing education of all community members by implementing organized and closely observed distance learning [38]. The principal leadership can promote a shift towards a digital culture by creating an open discussion environment where the educational community can perceive technological advancements and incorporating digital material into teaching models as a chance to enhance results instead of a challenge to conquer. They should concentrate on the procedural aspects and the values and convictions of teachers and students [45]. The impact of technology on education varies across societies, which may be due to differences in policy environments, such as technological infrastructure policy and policies surrounding the utilization of ICT. In other words, a country's policies can influence how teachers decide to integrate technology into their teaching methods. According to research conducted in Korea, the existence of technology integration policies initiated by educational authorities is a crucial factor that affects teacher's decision to use technology [12].

Additionally, in Hong Kong, policies that enhance teacher's professional development in ICT use and support the provision of resources have been found to facilitate the implementation of ICT. However, despite these findings, little scholarly attention has been given to the potential roles of educational systems and policy contexts in shaping technology integration beyond individual and school-level characteristics. A recent study emphasizes the importance of considering the role of ICT policy environments in shaping technology-enabled learning and its determinants beyond teacher and school-level factors [77]. The response to national policies can vary based on contextual factors, and there are two different methods for implementing school digitalization. The first method emphasizes competitiveness and provides a positive teacher environment, including dedicated support organizations and ample access to digital technology. The second method emphasizes local agreement on policy interpretation and compliance [37].

Compliance with policies is an instrument for assessing school evaluation. Monitoring and evaluating progress consistently are crucial for determining the implementation of digital school transformation to ensure effective project development. It involves evaluating the consistency of achievements with planned objectives and identifying any critical issues that arise during development. Progress should be regularly reported to provide stakeholders with a clear understanding of what has been achieved. From an outcome perspective, it is essential to identify and measure the produced changes, particularly in terms of how it impacts school function management and improves the skills of both teachers and students [11].

3) RQ 3. WHAT ARE THE MODELS OR FRAMEWORKS FOR DIGITAL TRANSFORMATION IN SECONDARY SCHOOLS?

After conducting a comprehensive literature review, the authors identified nine frameworks and four models used in the digital transformation of secondary schools. Our findings are presented in Table 9.

TABLE 9. Overview of digital transformation in secondary school's indicators.

Reference	Framework/Model
[39], [59]	The Technological Pedagogical Content Knowledge (TPACK) framework
[57]	OpenSciEd framework
[58]	IDI school model
[60]	TDC framework, TPACK framework, SAMR model
[61]	Pedagogical framework for STEM learning environments
[62]	D-LIFE framework
[63]	SAMR model
[64]	Digitalization framework for Schools revolution
[45]	Educational Digital Resources (EDRs) model
[65]	Principal e-leadership affect ICT transformation model
[35], [66]	DigComp framework
[67]	National e-Learning Center's (NELC's) Future eLearning Action Framework
[50]	Framework for Digitally Mature Schools (FDMS)

The standard model or framework that has been developed from the literature to explain implementing the vision of digital transformation's framework or model that was conducted for secondary schools. Technological Pedagogical Content Knowledge (TPACK) is a well-known framework for enabling an understanding to transform teaching and learning using ICT resources. According to Koehler and Mishra (2009), the TPACK framework is made up of seven elements, including [39]:

1. Technology Knowledge (TK) includes knowledge of digital and low-tech technologies such as the internet, videos, interactive whiteboards, and software.
2. Content Knowledge (CK) pertains to the knowledge of the subject matter to be taught and learned.
3. Pedagogical Knowledge (PK) covers teaching strategies and educational procedures such as lesson planning, assessment, and classroom management.
4. Pedagogical Content Knowledge (PCK) entails fusing pedagogy with subject matter to create better instructional techniques.
5. Technological Content Knowledge (TCK) comprises understanding how technology can display information.
6. Technological Pedagogical Knowledge (TPK) involves understanding how to teach using various technologies effectively.
7. Technological-Pedagogical-Content-Knowledge (TPACK) encompasses teachers' knowledge to integrate technology into specific subject areas. Therefore, it is logical to comprehend the intricate interplay among these three crucial knowledge components (PK, CK, TK) in terms of teaching subject-specific content using appropriate pedagogical methods and technologies.

The present study employed the TPACK framework to investigate how teachers utilized Information and ICT resources to augment their instruction. It comprises three interdependent knowledge components that synergistically generate the specific knowledge required for effective teaching. This study underscores the imperative role of combining these components in successfully integrating ICT into teaching and learning, which is fundamental for developing and delivering quality subject lessons. Given its significance, teachers should become familiar with the TPACK framework, as it can help them design and deliver meaningful technology-enhanced lessons [59].

The TPACK framework offers a more extensive and comprehensive approach to partially addressing the limitations of the SAMR model. The SAMR model is a descriptive tool for illustrating that digital technologies can elevate pedagogy by either enhancing it through substitution and augmentation or transforming it through modification and redefinition [63]. Schools and teacher training programs have largely embraced SAMR as a practical model for indicating the status of ICT development. While the SAMR model may be helpful for pre-service and in-service teachers by offering descriptive ''aim points'' to evolve their practice, it lacks concrete examples of the methods that might represent each stage or way of moving through the steps. It does not explicitly account for the supporting and necessary pedagogical, technological, and learning design changes. Even though it may be appealing due to its simplicity, SAMR only describes the different levels of subject-based technology integration. It reflects a limited understanding of what teacher education students need to know to develop the more all-encompassing and comprehensive set of skills required by an expanded view of digital competence. The Teacher Digital Competency (TDC) framework builds on TPACK and SAMR by targeting the skills and capabilities necessary to integrate digital resources into subject learning. Technical competence refers to a complete understanding of the operational mechanics of various digital technologies, such as mobile devices, apps, and network services. In contrast, technological competence focuses on the theoretical aspects of digital technologies, including their potential role in teaching and learning, as well as knowledge of the reasoning behind their inclusion in educational environments [60].

Large scale effort of the educational environment is the OpenSciEd framework. It is an effort aimed at broad implementation of the vision of the Framework for K-12 Science Education and the Next Generation Science Standards across the United States. This initiative is based on the premise that high-quality instructional materials can significantly impact science teaching and learning on a scale. In addition to accomplishing this objective project is collaboratively developing instructional materials for middle school science that promote the necessary practice shifts required to attain the outcomes mandated by the Framework for K-12 Science Education and the Next Generation Science Standards [57]. Another K-12 framework is The Digital Learning Implementation Framework for Education (D-LIFE). D-LIFE offers a framework for K-12 educational leaders to establish and assess the capacity for digital-age education in their schools by identifying critical criteria for digital learning. D-LIFE provides a holistic guide to inform school planning and an assessment tool for evaluating school capacity for learning. D-LIFE serves as a basis for K-12 education, allowing for the creation of additional evaluation tools, informing leadership training, and shaping International Baccalaureate (IB) Standards and Practices [62].

The study emphasizes school's need for a clear framework when setting up their digital institutions. It suggests a digital framework for schools to use when implementing educational technology tools and methods to profit from technological advancements. There are numerous technological instruments available to support the digital transformation of schools. Managing various components of school digitalization begins with policymakers and educators becoming aware of learning management systems to create individualized learning routes for students. Schools should know how to use teaching methods that adapt to the demands and expectations of digital learners while also changing the role of teachers. To cut costs, they want to use the most effective technological applications. Results in the context allow for the proposal of a

framework to direct the transformation of traditional schools into digital schools. This concept relies on developing digital resources and skills, learner motivations and potentials, social awareness, and parental awareness as four interrelated fundamental aspects required to achieve digital transformation successfully [64].

Acquiring digital transformation successfully, traditional schools need to become digital-based schools. The innovative digital school model (IDI school model) is an approach that provides both a research framework and a research-based model for schools to evaluate their practices with digital technologies. This model incorporates prior research on school improvement, innovation creation, and digital technology in education, considering learning as knowledge creation and digital technologies as a particular case of innovation. The model defines six key elements that describe an innovative digital school, including visions of the school, leadership, teaching community practices, pedagogical practices, school-level knowledge practices, and digital resources. The most effective schools regularly assess their practices and strive to enhance their approaches. The innovative digital school model is invaluable for schools and researchers [58].

According to a recent academic inquiry, the school principal's role in effecting changes in secondary education cannot be underestimated. In addition to the implementation of technology, developing teacher potential in teaching, and student's ability to use technology devices in learning, the role of the principal is to focus as a policy maker in transforming teaching and learning activities in school. Principal's perceptions regarding contextual factors and their pedagogical leadership in driving innovative transformation in education. Educational Digital Resources (EDRs) model is recognized as an essential resource for educational changes in the emerging knowledge society. Comprehending the factors influencing principal's decisions concerning digital content integration is crucial. Understanding this will significantly affect education policy and school leadership practices [45]. The findings of this study shed light on the principal's e-leadership as the primary transformation channel and the cornerstone of ICT transformation in a centralized educational system. As a result, the study advances knowledge of the essential element that will enable K–12 ICT transformation. The study also identified a more complex ICT transformation mechanism at various educational levels. A fine-grained analysis of other sub-factors, such as infrastructure, school culture, planning strategies, professional development, teacher ICT efficacy, and ICT integration competence, deserves further study given the complex influences of organizational and personal factors on teaching and learning change across primary and secondary schools [65].

Across science, technology, engineering, and mathematics (STEM) learning environments in secondary schools, the study literature strengthens the pedagogical framework for STEM learning environments, which includes the following types of design principles [61]:

1. General concepts.
2. Cross-curricular skills.
3. Teaching and learning methods.
4. Socio-emotional considerations.
5. Educational compatibility.

The study's design principles were applied to creating a hybrid (virtual, physical, formal, non-formal, and informal) STEM environment.

For student performance improvement in a digitized learning environment, digital competency skills are required. The DigComp framework, aimed at fostering and comprehending digital competence in Europe, is a significant policy that has been instrumental in shaping European education. The framework offers a comprehensive breakdown of digital competence, broadly categorized into five areas. They are information, communication, content creation, safety, and problem-solving. Each area is associated with a range of practical competencies to enhance learners' skills [66].

We also highlight the state of digital literacy and the prevalence of digital culture in Saudi Arabia as aspects of digital competencies. The study briefly overviews teacher digital literacy and development before, during, and after COVID-19. Within Saudi digital growth, measures taken after 2020 and lessons learned from the crisis are also discussed. The National e-Learning Center's (NELC's) Future eLearning Action Framework has identified major innovative movements to promote a digitalized philosophy that can reshape the possibilities for the future. The framework comprises ten strategies, including the following [67]:

1. Encourage innovation in online teaching and learning and foster a culture of innovation among administrators, teachers, and students.
2. Ensure that physical devices and teacher training resources are distributed equitably across urban and rural schools.
3. Provide incentives and compensation for teacher training and professional development related to online instruction.
4. Develop and implement policies and processes at the national and local levels that promote interactions in online classes and ensure opportunities for teacher-to-student and student-to-student interactions.
5. Review quality standards shared by international online learning experts, groups, and organizations and customize them according to national and local needs.
6. Increase the motivation and incentives for innovation among administrators, staff, and teachers.
7. Implement best practices identified by online learning experts to ensure the quality of online learning by basing benchmarks on these best practices.
8. Encourage teachers to be more innovative in their pedagogical or technological approaches, creating a supportive climate and culture for teacher innovation and encouraging them to innovate their instructional designs.

9. Establish a teacher-learning community program to develop the capacity for online learning tools and innovative pedagogical approaches.
10. Develop technology-facilitated, web-mediated guidance and instruction programs to integrate relevant principles into meaningful and sustained online learning experiences.

Overall, applying assessment frameworks or models facilitates the ability of schools to evaluate their current digital proficiency and identify areas that require enhancement. The developed framework and toolset assist educational institutions in assessing, promoting, and integrating digital technologies into their teaching, learning, and organizational practices [50].

4) RQ 4. HOW TO IMPLEMENT DIGITAL TRANSFORMATION IN SECONDARY SCHOOLS?

Implementing digital transformation in secondary schools requires a comprehensive approach that involves a range of stakeholders, including school administrators, school principals, teachers, students, parents, and IT professionals. The following are a few contributions summarized to implement digital transformation in secondary schools.

1. Develop digital school leadership: to examine the strategic impact of school principal leadership within the educational context. They provide a reliable tool for school principals to interact effectively with teachers and other stakeholders, including policymakers, in determining various priorities that must consider when implementing technology in the learning process in the classroom [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [52].
2. Develop digital transformation strategies: these strategies should clearly define the goals and objectives of the transformation, identify the key stakeholders involved, and establish a timeline for implementation. Additionally, the strategy should include an evaluation of the school's existing IT infrastructure and identify any required upgrades [11], [12], [45], [46], [49], [51], [56], [57].
3. Provide adequate training for teachers and staff: teachers and staff should be trained in using technology and incorporating it into their teaching. Staff members should be prepared to use new technology effectively. It could include workshops, training sessions, or online courses. The training should be ongoing as technology continues to evolve [11], [30], [35], [39], [75].
4. Invest in technology: in support their digital transformation strategy, schools are encouraged to make investments in technology such as laptops or tablets for students, interactive whiteboards for classrooms, and software to facilitate the management of digital assignments and assessments [8], [46], [51], [53], [64], [69], [70], [72], [73], [76], [77], [78], [79], [81], [82], [84], [88].
5. Implement digital assessments: involving teachers, students, and stakeholders in the process of digital transformation is essential. To ensure their engagement, conducting surveys could be a valuable approach to gather their opinions on the preferred types of technology to be integrated into the classroom and how they want to utilize them [13], [29], [31], [33], [54], [55], [85].
6. Develop a digital citizenship program: as technology use becomes more prevalent, students must learn about responsible digital conduct. Therefore, schools should establish a digital citizenship initiative that instructs students on online safety measures, safeguarding their privacy, and utilizing technology ethically and responsibly [28], [32], [45], [66], [80].
7. Monitor and evaluate progress: to ensure the success of digital transformation in schools, ongoing monitoring and evaluation of its progress are essential. It includes careful tracking of the implementation and usage of technology in the classroom, assessing student performance on digital assessments, and seeking feedback from teachers, students, and parents to refine and improve the process continually [13], [50], [58], [59], [62], [68], [86].

Secondary schools can successfully adopt digital transformation by using these strategies to make learning more effective and engaging for their students.

III. DISCUSSION AND LIMITATIONS

A. DISCUSSION

The challenges in implementing digital transformation in secondary schools based on SLR results of 65 selected articles it can be concluded that: (1) poor internet infrastructure, insufficient teacher training, disrupted information flow, uncomfortable home learning environments, uneven access to resources, and differing levels of academic proficiency [30], [38], [85]; (2) insufficient digital competencies among educators regarding of their knowledge and skills related to digital transformation [11], [67]; (3) integrating available technology into teaching practices poses several challenges for educators [29], [39], [53]; (4) progress has yet to be observed in addressing the emotional and motivational challenges teachers face or upgrading the digital infrastructure in schools. These various approaches and concepts underscore the difficulty of school improvement, especially in digital transformation, while emphasizing the critical need for ongoing digital advancement [34]; (5) preparing the next generation for diverse job markets and social structures necessitates not only the incorporation of technology but also a restructuring of school curricula and a transformation of the broader teaching and learning culture [44]; (6) aligning education with the demands of a digital society [45]; (7) the lack of a detailed model that outlines the specific requirements for using computers in education according to grade, subject, and context results in tangible improvements in learning outcomes. It is essential for these educational models not only to address the necessary hardware and software but also to include adequate training and support activities for teachers to adopt them effectively [56]; and (8) limited use of technology, teacher resistance to using ICTs for professional purposes, insufficient stakeholder involvement in promoting innovation within schools, a lack of vision or strategy for ICT

implementation in some institutions, technical difficulties associated with using ICTs, and the presence of digital tools in a school does not guarantee their usage by teachers. Other barriers to ICT integration include a lack of leadership and a shared vision for digital innovation, inadequate assessment and intervention to facilitate ICT integration, and a lack of shared understanding among school personnel regarding the role of ICTs in curriculum implementation [51].

Developing effective methods are imperative to address the challenges faced when implementing digital transformation in high schools. Strategies are necessary to encounter the specific challenges that arise during this process, including: (1) the process of digital transformation has the potential to offer important lessons to decision-makers in the field of education who are preparing to undertake their digital transformation efforts [49]; (2) government's sustained efforts to allocate sufficient resources and support the digitalized education system, the crucial aspect of the matter is the progress and advancements made by school leaders. Previous studies have established a link between the efficacy of ICT implementation in schools and the technology leadership demonstrated by principals. The effectiveness of integrating technology in school's depend on the quality of guidance and leadership provided by principals, as it directly impacts the extent to which teachers fully utilize ICT [46], [51]; (3) educational policies for digital transformation should encompass school principals, considering contextual factors such as school size, complexity, and digital culture, as well as principal's age, teaching, and leadership experience. Principal's leadership in promoting digital culture transformation should not rely on their authority or bureaucratic influence alone [45]; (4) integrating e-tutoring programs on a global scale is essential to improving digital transformation in educational systems [12], [56]; (5) implementing 21st century teaching methodologies and skills requires incorporating digital tools to foster creativity, critical thinking, and problem-solving abilities among learners. The curriculum should promote digital competence readiness, focusing on planning learner-centered engagements. Teachers should receive training to enhance their self-awareness for learner-centered active learning and support them to act as change agents. School-based management should receive training to facilitate reforms while encouraging bottom-up school-invocation actions. Defining the role of technology in the curriculum is essential, along with the promotion of innovative pedagogies [51]; (6) technology integration in education is anticipated to mitigate the challenges posed by the wider digital transformation in society and promote the development of digital literacy. Studies indicate that there may be a correlation between school development goals, leadership practices, and the degree of technology integration achieved [44]; and (7) identify the needs of stakeholders and incorporate them into a new organizational strategy, which can provide valuable evidence and insights to enhance the rationale for transformation. In education, for instance, teachers' mobile and hybrid learning needs encompass their confidence in using technology, integrating it into pedagogical practices, and personal support in using technology. Consulting organizations, policymakers, and influential organizations can offer valuable guidance to develop an effective strategy for DT in education. Adopting a DT strategy allows education systems and school leaders to obtain a roadmap that facilitates technology integration in their practices [11], [49].

The accuracy of the strategy in implementing digital transformation has been proven to transform most of the education systems. However, with the development of time, technology in the education world provides new hope for developing countries to revitalize and face the challenges of digital transformation, especially in secondary education. Developing countries have high expectations for using technology to drive digital transformation toward economic prosperity [92]. Several developing countries consider digital technology in education to have interests as follows [93]: (1) to ensure that every individual has the necessary knowledge, skills, competencies, and lifelong learning opportunities to adapt and work in an environment filled with technology; (2) to enable communities to harness digital technology's potential benefits for expanding access to quality education; and (3) to improve the quality and relevance of lifelong learning.

Digital technology transformation recommends policies provided to developing countries to utilize the benefits of the digital revolution effectively, especially in addressing educational and pedagogical challenges. Developing countries also need to develop comprehensive digital-based education strategies to shape the digital education agenda in their country. Despite the varying levels of technological proficiency or familiarity with digital learning approaches, all instructors were expected to adapt promptly to virtual platforms and novel pedagogical strategies, even during regular hours. The sudden and prolonged lockdown has resulted in a new normal with a heightened digital emphasis. For example, a significant proportion of the Indian populace remains uncertain due to their lack of access to technology and dependable internet connectivity. As society transitions towards a digital world, these individuals fall behind and suffer setbacks [30]. The transformation of virtual classes in digital platforms is necessary because it poses a significant challenge in developing countries where information infrastructure for remote learning is inadequate [70].

Developed countries are undergoing significant changes in information technology and acquiring the necessary knowledge to manage it. The growth of the Online Service Index (OSI) and the adjusted ICT Development Index (IDI_adj) - which describe the quality of access to public online services and the level of ICT development in developed countries - has led to a cumulative real per capita GDP growth of almost 0.55%. Although this is sufficient to cover the potential for new progressive innovation, more straightforward and user-friendly technology will be the primary driver of growth in the digitalization framework. The transformation of information technology positively impacts the well-being

of developed countries nowadays [94]. The economic benefits of integrating digital technology into the education system are considerable, as it increases GDP growth and employment opportunities. It is because digitalization enhances worker productivity and improves education quality worldwide [54].

B. LIMITATIONS

Digital transformation has become a driving force to improve the quality of education in developed and developing countries. In addition, our study findings indicate that (RQ1) the state-of-the-art research on DT in secondary schools is limited between 2012-2023. Additionally, (RQ2) we identified significant indicators for implementing digital transformation in secondary schools solely based on the full reading of selected literature without any systematic basis or additional literature. Thus, (RQ3) as a result of our investigation, the standard model or framework developed by previous researchers needs to be more comprehensive to be used by all secondary schools worldwide, as it depends on each school's unique needs. Henceforth, there is no one-size-fits-all approach. Finally, in (RQ4), based on the selected literature, our suggestion is a stepwise strategy for implementing digital transformation in secondary schools. This strategy is expected to successfully adopt digital transformation to make learning more effective, efficient, and enjoyable for all stakeholders involved in teaching and learning.

Furthermore, a systematic literature review identified an opportunity (RQ3) to develop a standardized model or framework specifically designed for secondary schools. It is necessary because existing models and frameworks only accommodate some of the needs of secondary schools due to their unique characteristics. Therefore, a specialized model or framework is required. The study reveals certain constraints in the proposed framework. Firstly, the framework needs to consider the potential advantages of digitizing schools. Secondly, it restricts the interconnectedness between its primary dimensions, presenting transformational modifications as unidirectional changes for clarity. Thirdly, the framework's social and parental consciousness component, which is pivotal for evaluating the effectiveness of transformative alterations for educational transformation, suffers from variations in quality and quantity [64]. Therefore, in-depth research is necessary to enhance existing models or frameworks to create a comprehensive model or framework.

This article needs to address the challenges encountered while implementing digital transformation extensively. Some obstacles were identified, including the need for more skilled human resources, inadequate financial resources, insufficient IT equipment, the absence of standardized digital policies, and limited involvement of school principals in shaping digital policies. Despite our best-efforts figure, our analysis of studies for implementing digital transformation in secondary schools contains various flaws and potential weaknesses that could compromise its reliability. One such restriction is the limited number of 65 articles that matched our inclusion criteria. As a result, more investigation is required to fully comprehend the scope and potential of DT in secondary school. A larger sample size of articles would result in more specific findings regarding the effects and gap identification, the immediate impacts of DT implementation in secondary schools, the importance of technology used, best practices in DT methodologies, and comprehensive frameworks for DT assessment in secondary schools. This review does not rule out the possibility of bias in selecting studies. Not all journal paper titles were personally read as part of our search procedure. However, we did not limit our literature review and instead used several database searches. Potentially relevant publications were missed due to bias in the database selection or search strings used. Discrimination in the database selection or the utilized search terms prevented finding possibly relevant papers.

IV. CONCLUSION AND FUTURE RESEARCH

A. CONCLUSION

A protocol and review strategy were created to analyze the textual data, incorporating established methodologies utilized by previous study. These approaches were utilized to systematize and structure the information obtained from the texts systematically and coherently. A systematic literature review was performed on 65 papers to enhance a better understanding of digital transformation in secondary schools. In comparison to previous systematic reviews, this study makes significant contributions in the following ways:

1. To cover more recent research on digital transformation.
2. To propose innovative research questions, including a unique discussion on past experiences implementing the background knowledge required for successful digital transformation.
3. To present potentially critical topics for a research roadmap on introducing digital transformation in secondary schools.

In pursuit of addressing the research questions, RQ1 aimed to determine the latest advancements in digital transformation in secondary schools between 2012 to 2023. We found that the current research focused on the actors and stakeholders involved in DT and the technologies used. RQ2 focused on identifying critical indicators for researching digital transformation in secondary schools, which included school leadership, digital competencies, professional development, DT governance, access to technologies, school evaluation, and secondary school policy. Meanwhile, answers to RQ3 revealed nine frameworks and four models applied to secondary schools in digital transformation. Finally, RQ4 unfolded various strategies for implementing digital transformation in secondary schools, including developing digital school leadership, developing digital transformation strategies, providing adequate training for teachers and staff, investing in technology, implementing digital assessments, creating a digital citizenship program, and monitoring and evaluating progress.

This review has identified several key areas regarding digital transformation in secondary schools, following: (1) there

is a need to define the concept of digital transformation in this context clearly; (2) fostering the trend topic dialogue between the communities of secondary schools is crucial to ensuring the successful implementation of digital transformation initiatives. Creating specific tools for problem formulation will also aid in this process; (3) gaining a comprehensive understanding of effective methods for conducting digital transformation in secondary schools is essential; (4) stimulating to create of standard models and frameworks will ensure consistency and coherence in digital transformation efforts; and (5) these areas merit further investigation and development to facilitate successful digital transformation in secondary schools. The shift towards digital media in education demands that conventional learning materials be upgraded to digital alternatives. Additionally, educators must be proficient in emerging technologies, requiring appropriate training and support. The article highlights training as a vital tool for overcoming educators' hesitation in integrating technology into their teaching practices. Nonetheless, the substantial time and financial investment required for teacher training and IT infrastructure upgrades remains the major obstacle. These factors represent crucial considerations for institutions embarking on the digital transformation journey.

B. FUTURE RESEARCH

Future research should focus on various aspects of digital transformation, particularly in secondary schools. This research should deepen our understanding of problem-solving processes, analyze the challenges and obstacles that disrupt successful digital transformation methods, and incorporate a wide range of up-to-date research sources from other various digital libraries.

ACKNOWLEDGMENT

The authors would like to thank the School of Electrical Engineering and Informatics, Bandung Institute of Technology (ITB), for assistance in conducting this research.

REFERENCES

[1] J. H. S. Gómez, F. N. Díaz-Piraquive, Y. de J. Muriel-Perea, and A. D. Peláez, "Advances, opportunities, and challengesin the digital transformation of HEIs in Latin America," 2021, pp. 55–75, doi: 10.1007/978-981-16-3941-8_4.
[2] M. Simonette, M. Magalhães, and E. Spina, "Digital transformation of academic management: All the tigers come at night," 2021, pp. 77–92, doi: 10.1007/978-981-16-3941-8_5.
[3] A. Milroy, "Digital transformation in the education sector."
[4] World Economic Forum. (2020). *Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution*. [Online]. Available: http://www.weforum.org
[5] *Digital Transformation: Becoming an Innovative, Agile and Collaborative Organization, Fit for Purpose in the Digital Age*, United Nation Environment Programme, Nairobi, Kenya, 2022.
[6] A. Haleem, M. Javaid, M. A. Qadri, and R. Suman, "Understanding the role of digital technologies in education: A review," *Sustain. Oper. Comput.*, vol. 3, pp. 275–285, Jan. 2022, doi: 10.1016/j.susoc.2022.05.004.
[7] Y. Rosmansyah, B. L. Putro, A. Putri, and N. B. Utomo, "A simple model of smart learning environment," *Interact. Learn. Environments*, vol. 2022, pp. 1–22, Jan. 2022, doi: 10.1080/10494820.2021.2020295.
[8] Z. N. Khlaif and S. Farid, "Transforming learning for the smart learning paradigm: Lessons learned from the palestinian initiative," *Smart Learn. Environments*, vol. 5, no. 1, pp. 1–12, Dec. 2018, doi: 10.1186/s40561-018-0059-9.
[9] A. Qazi, G. Hardaker, I. S. Ahmad, M. Darwich, J. Z. Maitama, and A. Dayani, "The role of information & communication technology in elearning environments: A systematic review," *IEEE Access*, vol. 9, pp. 45539–45551, 2021, doi: 10.1109/ACCESS.2021.3067042.
[10] S. Ali, Y. Hafeez, M. Humayun, N. S. M. Jamail, M. Aqib, and A. Nawaz, "Enabling recommendation system architecture in virtualized environment for e-learning," *Egyptian Informat. J.*, vol. 23, no. 1, pp. 33–45, Mar. 2022, doi: 10.1016/j.eij.2021.05.003.
[11] C. G. Demartini, L. Benussi, V. Gatteschi, and F. Renga, "Education and digital transformation: The 'Riconnessions' project," *IEEE Access*, vol. 8, pp. 186233–186256, 2020, doi: 10.1109/ACCESS.2020.3018189.
[12] S. Doukakis, G. Michalopoulou, and T. Chira, "The integration of e-tutoring programs in secondary education—A digital transformation strategy," in *Proc. 5th South-East Eur. Design Autom., Comput. Eng., Comput. Netw. Social Media Conf. (SEEDA-CECNSM)*, Sep. 2020, pp. 1–5, doi: 10.1109/SEEDA-CECNSM49515.2020.9221809.
[13] A. Mišianiková, V. Hubenáková, M. KireŠ, M. Babincáková, D. Šveda, and P. J. Šafárik, "Assessment of digitalization in primary and secondary schools by SELFIE survey as a part of school leaders training," in *Proc. 19th Int. Conf. Emerg. eLearn. Technol. Appl. (ICETA)*, Nov. 2021, pp. 252–258, doi: 10.1109/ICETA54173.2021.9726580.
[14] G. Kalogeratos and C. Pierrakeas, "Knowledge and skills of the digital transformation of the Greek public school in the post COVID era," in *Proc. 13th Int. Conf. Inf., Intell., Syst. Appl. (IISA)*, Jul. 2022, pp. 1–7, doi: 10.1109/IISA56318.2022.9904416.
[15] M. N. Khan, "Determining mobile payment adoption: A systematic literature search and bibliometric analysis," *Cogent Bus. Manage.*, vol. 8, no. 1, pp. 1–10, Jan. 2021, doi: 10.1080/23311975.2021.1893245.
[16] G. Lame, "Systematic literature reviews: An introduction," in *Proc. Int. Conf. Eng. Design*, Jul. 2019, pp. 1633–1642, doi: 10.1017/dsi.2019.169.
[17] I. Siksnelyte-Butkiene, "A systematic literature review of indices for energy poverty assessment: A household perspective," *Sustainability*, vol. 13, no. 19, p. 10900, Sep. 2021, doi: 10.3390/su131910900.
[18] W. Mengist, T. Soromessa, and G. Legese, "Method for conducting systematic literature review and meta-analysis for environmental science research," *MethodsX*, vol. 7, Feb. 2020, Art. no. 100777, doi: 10.1016/j.mex.2019.100777.
[19] M. J. Page et al., "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *BMJ*, vol. 372, p. n71, Mar. 2021, doi: 10.1136/bmj.n71.
[20] R. Pranckutė, "Web of science (WoS) and Scopus: The titans of bibliographic information in today's academic world," *Publications*, vol. 9, no. 1, p. 12, Mar. 2021.
[21] M. Visser, N. J. van Eck, and L. Waltman, "Large-scale comparison of bibliographic data sources: Scopus, web of science, dimensions, crossref, and Microsoft academic," *Quant. Sci. Stud.*, vol. 2, no. 1, pp. 20–41, Apr. 2021, doi: 10.1162/qss_a_00112.
[22] A. Martín-Martín, E. Orduna-Malea, M. Thelwall, and E. D. López-Cózar, "Google scholar, web of science, and Scopus: A systematic comparison of citations in 252 subject categories," *J. Informetrics*, vol. 12, no. 4, pp. 1160–1177, Nov. 2018, doi: 10.1016/j.joi.2018.09.002.
[23] F. Creswell, "Health workers' perspectives on the occurrence and management of antimicrobial resistance at the human-animal-environment interface in Uganda," *Notes Queries*, vol. 4, no. 25, p. 577, Jan. 1868.
[24] S. Patole, *Principles and Practice of Systematic Reviews and Meta-Analysis*. 2021, doi: 10.1007/978-3-030-71921-0.
[25] S. Boswell and C. Cannon, *Introduction to Nursing Research Incorporating Evidence-Based Practice*.
[26] L. G. Ford and B. M. Melnyk, "The underappreciated and misunderstood PICOT question: A critical step in the EBP process," *Worldviews Evidence-Based Nursing*, vol. 16, no. 6, pp. 422–423, Dec. 2019, doi: 10.1111/wvn.12408.
[27] L. M. C. Benavides, J. A. T. Arias, M. D. A. Serna, J. W. B. Bedoya, and D. Burgos, "Digital transformation in higher education institutions: A systematic literature review," *Sensors*, vol. 20, no. 11, pp. 1–22, 2020, doi: 10.3390/s20113291.
[28] T. De Clue and M. Provance, "Predicting digital success: Identifying computer science talent in K12 students," *J. Comput. Sci. Coll.*, vol. 33, no. 5, pp. 108–114, 2018.
[29] W. Li, W. Gao, W. Fu, and Y. Chen, "A moderated mediation model of the relationship between primary and secondary school teachers' digital competence and online teaching behavior," *Frontiers Educ.*, vol. 6, pp. 1–11, Sep. 2021, doi: 10.3389/feduc.2021.744950.

[30] B. Singh, R. Zamaletdinov, B. Kaur, and J. Singh, "Virtual professional learning for school teachers to support them in online environment," *Frontiers Educ.*, vol. 7, pp. 1–10, May 2022, doi: 10.3389/feduc.2022.802882.

[31] S. Panesi, S. Bocconi, and L. Ferlino, "Promoting students' well-being and inclusion in schools through digital technologies: Perceptions of students, teachers, and school leaders in Italy expressed through SELFIE piloting activities," *Frontiers Psychol.*, vol. 11, pp. 1–12, Jul. 2020, doi: 10.3389/fpsyg.2020.01563.

[32] D. T. Bui, T. T. Nhan, H. T. T. Dang, and T. T. T. Phung, "Online learning experiences of secondary school students during COVID-19—Dataset from Vietnam," *Data Brief*, vol. 45, Dec. 2022, Art. no. 108662, doi: 10.1016/j.dib.2022.108662.

[33] I. DeCoito and M. Estaiteyeh, "Online teaching during the COVID-19 pandemic: Exploring science/STEM teachers' curriculum and assessment practices in Canada," *Disciplinary Interdiscipl. Sci. Educ. Res.*, vol. 4, no. 1, Dec. 2022, doi: 10.1186/s43031-022-00048-z.

[34] M. Rauseo, A. Harder, D. Glassey-Previdoli, A. Cattaneo, S. Schumann, and S. Imboden, "Same, but different? Digital transformation in Swiss vocational schools from the perspectives of school management and teachers," *Technol., Knowl. Learn.*, vol. 2022, pp. 407–427, Dec. 2022.

[35] A. A. P. Cattaneo, C. Antonietti, and M. Rauseo, "How digitalised are vocational teachers? Assessing digital competence in vocational education and looking at its underlying factors," *Comput. Educ.*, vol. 176, Jan. 2022, Art. no. 104358, doi: 10.1016/j.compedu.2021.104358.

[36] U. Gustafsson, "Taking a step back for a leap forward: Policy formation for the digitalisation of schools from the views of Swedish national policymakers," *Educ. Inquiry*, vol. 12, no. 4, pp. 329–346, Oct. 2021, doi: 10.1080/20004508.2021.1917487.

[37] U. Gustafsson, "Size matters: Contextual factors in local policy translations of national school digitalisation policy," *Educ. Inf. Technol.*, vol. 27, no. 8, pp. 11741–11758, Sep. 2022.

[38] K. Potyrała, N. Demeshkant, K. Czerwiec, B. Jancarz-Łanczkowska, and Ł. Tomczyk, "Head teachers' opinions on the future of school education conditioned by emergency remote teaching," *Educ. Inf. Technol.*, vol. 26, no. 6, pp. 7451–7475, Nov. 2021, doi: 10.1007/s10639-021-10600-5.

[39] E. B. Demissie, T. O. Labiso, and M. W. Thuo, "Teachers' digital competencies and technology integration in education: Insights from secondary schools in Wolaita zone, Ethiopia," *Social Sci. Humanities Open*, vol. 6, no. 1, 2022, Art. no. 100355, doi: 10.1016/j.ssaho.2022.100355.

[40] M. Håkansson Lindqvist and F. Pettersson, "Digitalization and school leadership: On the complexity of leading for digitalization in school," *Int. J. Inf. Learn. Technol.*, vol. 36, no. 3, pp. 218–230, Jun. 2019, doi: 10.1108/IJILT-11-2018-0126.

[41] M. Afshari, K. A. Bakar, W. S. Luan, and S. Siraj, "Factors affecting the transformational leadership role of principals in implementing ICT in schools," *Turkish Online J. Educ. Technol.*, vol. 11, no. 4, pp. 164–176, 2012.

[42] M. Aas, K. F. Vennebo, and K. A. Halvorsen, "Bench learning—An action research program for transforming leadership and school practices," *Educ. Action Res.*, vol. 10, pp. 1–17, Jan. 2019, doi: 10.1080/09650792.2019.1566084.

[43] J. Mogas, R. Palau, M. Fuentes, and G. Cebrián, "Smart schools on the way: How school principals from catalonia approach the future of education within the fourth industrial revolution," *Learn. Environ. Res.*, vol. 25, no. 3, pp. 875–893, Oct. 2022, doi: 10.1007/s10984-021-09398-3.

[44] M. Ruloff and D. Petko, "School principals' educational goals and leadership styles for digital transformation: Results from case studies in upper secondary schools," *Int. J. Leadership Educ.*, vol. 2021, pp. 1–19, Dec. 2021, doi: 10.1080/13603124.2021.2014979.

[45] F. Navaridas-Nalda, M. Clavel-San Emeterio, R. Fernández-Ortiz, and M. Arias-Oliva, "The strategic influence of school principal leadership in the digital transformation of schools," *Comput. Hum. Behav.*, vol. 112, Nov. 2020, Art. no. 106481, doi: 10.1016/j.chb.2020.106481.

[46] S. Ghavifekr and S. Y. Wong, "Technology leadership in Malaysian schools: The way forward to education 4.0—ICT utilization and digital transformation," *Int. J. Asian Bus. Inf. Manage.*, vol. 13, no. 2, pp. 1–18, Jul. 2021, doi: 10.4018/IJABIM.20220701.oa3.

[47] I. Berkovich and T. Hassan, "Principals' digital transformational leadership, teachers' commitment, and school effectiveness," *Educ. Inquiry*, vol. 2023, pp. 1–18, Feb. 2023, doi: 10.1080/20004508.2023.2173705.

[48] M. Afshari, S. Ghavifekr, S. Siraj, and R. S. A. Samad, "Transformational leadership role of principals in implementing informational and communication technologies in schools," *Life Sci. J.-Acta Zhengzhou Univ. Overseas Ed.*, vol. 9, no. 1, pp. 1–4, 2012.

[49] A. M. McCarthy, D. Maor, A. McConney, and C. Cavanaugh, "Digital transformation in education: Critical components for leaders of system change," *Social Sci. Humanities Open*, vol. 8, no. 1, 2023, Art. no. 100479, doi: 10.1016/j.ssaho.2023.100479.

[50] N. B. Redjep, I. Balaban, and B. Zugec, "Assessing digital maturity of schools: Framework and instrument," *Technol., Pedagogy Educ.*, vol. 30, no. 5, pp. 643–658, Oct. 2021, doi: 10.1080/1475939X.2021.1944291.

[51] J. S. Quaicoe, A. A. Ogunyemi, and M. L. Bauters, "School-based digital innovation challenges and way forward conversations about digital transformation in education," *Educ. Sci.*, vol. 13, no. 4, p. 344, Mar. 2023.

[52] A. A. Genlott, Å. Grönlund, O. Viberg, and A. Andersson, "Leading dissemination of digital, science-based innovation in school—A case study," *Interact. Learn. Environ.*, vol. 10, pp. 1–11, Jul. 2021, doi: 10.1080/10494820.2021.1955272.

[53] C. Blundell, K.-T. Lee, and S. Nykvist, "Using dual systems theory to conceptualise challenges to routine when transforming pedagogy with digital technologies," *Teachers Teach.*, vol. 25, no. 8, pp. 937–954, Nov. 2019, doi: 10.1080/13540602.2019.1652161.

[54] A. Ibrayeva and S. Yegemberdiyeva, "Assessment of digital transformation in the education system of Kazakhstan," *Econ. Ser. Bull.*, no. 4, pp. 152–160, Jan. 2022, doi: 10.32523/2789-4320-2022-4-152-160.

[55] P. Irfan and Y. Ph, "A review of digital transformation of education in Oman," *J. Bus. Manage. Accounting*, vol. 5, no. 2, pp. 6–8, 2019, doi: 10.29226/TR1001.2021.260.

[56] "Digital transformation in education: Hungary versus Turkey," 2020.

[57] D. C. Edelson, B. J. Reiser, K. L. McNeill, A. Mohan, M. Novak, L. Mohan, R. Affolter, T. A. W. McGill, Z. E. B. Bracey, J. D. Noll, S. M. Kowalski, D. Novak, A. S. Lo, C. Landel, A. Krumm, W. R. Penuel, K. Van Horne, M. González-Howard, and E. Suárez, "Developing research-based instructional materials to support large-scale transformation of science teaching and learning: The approach of the OpenSciEd middle school program," *J. Sci. Teacher Educ.*, vol. 32, no. 7, pp. 780–804, Oct. 2021, doi: 10.1080/1046560X.2021.1877457.

[58] L. Ilomäki and M. Lakkala, "Digital technology and practices for school improvement: Innovative digital school model," *Res. Pract. Technol. Enhanced Learn.*, vol. 13, no. 1, pp. 1–32, Dec. 2018.

[59] A. R. Molotsi, "The use of ICT resources to transform teaching at secondary schools in the Bojanala district, Northwest province," *South Afr. J. Educ.*, vol. 42, no. 1, pp. 1–10, Dec. 2022, doi: 10.15700/saje.v42ns1a2098.

[60] G. Falloon, "From digital literacy to digital competence: The teacher digital competency (TDC) framework," *Educ. Technol. Res. Develop.*, vol. 68, no. 5, pp. 2449–2472, Oct. 2020, doi: 10.1007/s11423-020-09767-4.

[61] T. Mäkelä, K. Fenyvesi, M. Kankaanranta, D. Pnevmatikos, and P. Christodoulou, "Co-designing a pedagogical framework and principles for a hybrid STEM learning environment design," *Educ. Technol. Res. Develop.*, vol. 70, no. 4, pp. 1329–1357, Aug. 2022, doi: 10.1007/s11423-022-10114-y.

[62] C. A. Haynes and K. Shelton, "Beyond the classroom: A framework for growing school capacity in a digital age," *J. Res. Technol. Educ.*, vol. 50, no. 4, pp. 271–281, Oct. 2018, doi: 10.1080/15391523.2018.1451791.

[63] C. Blundell, K.-T. Lee, and S. Nykvist, "Moving beyond enhancing pedagogies with digital technologies: Frames of reference, habits of mind and transformative learning," *J. Res. Technol. Educ.*, vol. 52, no. 2, pp. 178–196, Apr. 2020, doi: 10.1080/15391523.2020.1726235.

[64] F. M. Yehya, "Promising digital schools: An essential need for an educational revolution," *Pedagogical Res.*, vol. 6, no. 3, Jul. 2021, Art. no. em0099, doi: 10.29333/pr/11061.

[65] B. Wu, X. Yu, and Y. Hu, "How does principal e-leadership affect ICT transformation across different school stages in K-12 education: Perspectives from teachers in Shanghai," *Brit. J. Educ. Technol.*, vol. 50, no. 3, pp. 1210–1225, May 2019, doi: 10.1111/bjet.12766.

[66] A. D. Olofsson, J. O. Lindberg, A. Young Pedersen, A.-T. Arstorp, C. Dalsgaard, E. Einum, F. Caviglia, L. Ilomäki, M. Veermans, P. Häkkinen, and S. Willermark, "Digital competence across boundaries–beyond a common Nordic model of the digitalisation of K-12 schools?" *Educ. Inquiry*, vol. 12, no. 4, pp. 317–328, Oct. 2021, doi: 10.1080/20004508.2021.1976454.

[67] A. Alghamdi, "Digital transformation within Saudi education system: 2020 and beyond," *Educ. Rev. USA*, vol. 6, no. 8, pp. 419–425, 2022.

[68] M. Dormann, S. Hinz, and E. Wittmann, "Improving school administration through information technology? How digitalisation changes the bureaucratic features of public school administration," *Educ. Manage. Admin. Leadership*, vol. 47, no. 2, pp. 275–290, Mar. 2019, doi: 10.1177/1741143217732793.
[69] S. Lovyagin, "Transform a physics course in middle school through personalized learning and digital platform," *Int. Forum Teach. Educ.*, vol. 1, pp. 1487–1496, May 2020, doi: 10.3897/ap.2.e1487.
[70] Q.-D. Pham, N.-N. Dao, T. Nguyen-Thanh, S. Cho, and H. C. Pham, "Detachable web-based learning framework to overcome immature ICT infrastructure toward smart education," *IEEE Access*, vol. 9, pp. 34951–34961, 2021, doi: 10.1109/ACCESS.2021.3062371.
[71] A. Bogliolo, S. Delpriori, G. M. Di Francesco, L. C. Klopfenstein, and B. D. Paolini, "Massive remote school trips: A case study," *IEEE Access*, vol. 9, pp. 165239–165251, 2021, doi: 10.1109/ACCESS.2021.3135463.
[72] K. Nadarajan, A. H. Abdullah, N. S. A. Alhassora, N. H. Ibrahim, J. Surif, D. F. Ali, N. M. Zaid, and M. H. Hamzah, "The effectiveness of a technology-based isometrical transformation flipped classroom learning strategy in improving students' higher order thinking skills," *IEEE Access*, vol. 11, pp. 4155–4172, 2023, doi: 10.1109/ACCESS.2022.3230860.
[73] A. Addone, R. De Donato, G. Palmieri, M. A. Pellegrino, A. Petta, V. Scarano, and L. Serra, "Novelette, a usable visual storytelling digital learning environment," *IEEE Access*, vol. 9, pp. 168850–168868, 2021, doi: 10.1109/ACCESS.2021.3137076.
[74] K. W. Griffin, C. Williams, C. M. Botvin, S. Sousa, and G. J. Botvin, "Effectiveness of a hybrid digital substance abuse prevention approach combining e-Learning and in-person class sessions," *Frontiers Digit. Health*, vol. 4, Aug. 2022, Art. no. 931276.
[75] M. Sailer, J. Murböck, and F. Fischer, "Digital learning in schools: What does it take beyond digital technology?" *Teach. Teacher Educ.*, vol. 103, Jul. 2021, Art. no. 103346, doi: 10.1016/j.tate.2021.103346.
[76] G. R. J. Mangione and G. Cannella, "Small school, smart schools: Distance education in remoteness conditions," *Technol., Knowl. Learn.*, vol. 26, no. 4, pp. 845–865, Dec. 2021, doi: 10.1007/s10758-020-09480-4.
[77] I. Han, S.-Y. Byun, and W. S. Shin, "A comparative study of factors associated with technology-enabled learning between the United States and South Korea," *Educ. Technol. Res. Develop.*, vol. 66, no. 5, pp. 1303–1320, Oct. 2018, doi: 10.1007/s11423-018-9612-z.
[78] S. K. Howard, L. Schrum, J. Voogt, and H. Sligte, "Designing research to inform sustainability and scalability of digital technology innovations," *Educ. Technol. Res. Develop.*, vol. 69, no. 4, pp. 2309–2329, Aug. 2021, doi: 10.1007/s11423-020-09913-y.
[79] J. K. Price, "Transforming learning for the smart learning environment: Lessons learned from the Intel education initiatives," *Smart Learn. Environments*, vol. 2, no. 1, pp. 1–12, Dec. 2015, doi: 10.1186/s40561-015-0022-y.
[80] T. Rasa and A. Laherto, "Young people's technological images of the future: Implications for science and technology education," *Eur. J. Futures Res.*, vol. 10, no. 1, pp. 1–15, Dec. 2022, doi: 10.1186/s40309-022-00190-x.
[81] V. Palladino and M. Guardado, "Extending the heritage language classroom? Experiences of digital technology use in two community schools in Alberta, Canada," *Lang. Cult. Curric.*, vol. 10, no. 2, pp. 1–18, 2017, doi: 10.1080/07908318.2017.1415923.
[82] M. Pifarré, "Using interactive technologies to promote a dialogic space for creating collaboratively: A study in secondary education," *Thinking Skills Creativity*, vol. 32, pp. 1–16, Jun. 2019, doi: 10.1016/j.tsc.2019.01.004.
[83] M. Corry, "Transforming and turning around low-performing schools: The role of online learning," *J. Educators Online*, vol. 11, no. 2, pp. 1–31, 2014. [Online]. Available: https://eric.ed.gov/?id=EJ1033256%0Ahttp://files.eric.ed.gov/fulltext/EJ1033256.pdf
[84] E. Muryukina and O. Gorbatkova, "Media educational technologies in teaching schoolchildren and students in the age of digital transformation," *Media Educ.*, vol. 18, no. 4, pp. 617–623, 2022, doi: 10.13187/me.2022.4.617.
[85] M. Szyszka, Ł. Tomczyk, and A. M. Kochanowicz, "Digitalisation of schools from the perspective of teachers' opinions and experiences: The frequency of ICT use in education, attitudes towards new media, and support from management," *Sustainability*, vol. 14, no. 14, p. 8339, Jul. 2022, doi: 10.3390/su14148339.
[86] S. Avdeeva, A. Uvarov, and K. Tarasova, "Digital transformation of schools and student's information and communication literacy," *Educ. Stud. Moscow*, no. 1, pp. 218–243, Mar. 2022, doi: 10.17323/1814-9545-2022-1-218-243.
[87] N. Bergdahl and M. Bond, "Negotiating (dis-)engagement in K-12 blended learning," *Educ. Inf. Technol.*, vol. 27, no. 2, pp. 2635–2660, Mar. 2022, doi: 10.1007/s10639-021-10714-w.
[88] F. Pettersson, "Understanding digitalization and educational change in school by means of activity theory and the levels of learning concept," *Educ. Inf. Technol.*, vol. 26, no. 1, pp. 187–204, Jan. 2021, doi: 10.1007/s10639-020-10239-8.
[89] E. S. Barry, J. Merkebu, and L. Varpio, "State-of-the-art literature review methodology: A six-step approach for knowledge synthesis," *Perspect. Med. Educ.*, vol. 11, no. 5, pp. 281–288, 2022, doi: 10.1007/s40037-022-00725-9.
[90] B. K. AlNuaimi, S. K. Singh, S. Ren, P. Budhwar, and D. Vorobyev, "Mastering digital transformation: The Nexus between leadership, agility, and digital strategy," *J. Bus. Res.*, vol. 145, pp. 636–648, Jun. 2022, doi: 10.1016/j.jbusres.2022.03.038.
[91] *Guidelines for ICT in Education Policies and Masterplans*, UNESCO, Paris, France, 2022.
[92] M. Matthess and S. Kunkel, "Structural change and digitalization in developing countries: Conceptually linking the two transformations," *Technol. Soc.*, vol. 63, Nov. 2020, Art. no. 101428, doi: 10.1016/j.techsoc.2020.101428.
[93] J. F. Kalolo, "Digital revolution and its impact on education systems in developing countries," *Educ. Inf. Technol.*, vol. 24, no. 1, pp. 345–358, Jan. 2019, doi: 10.1007/s10639-018-9778-3.
[94] A. N. Rasskazova and V. V. Yurgenson, "Determinants of digitalization in developed countries," in *Proc. CEUR Workshop*, vol. 3090, 2021, pp. 334–342.

TANTI MEISHANTI YULIANDARI received the bachelor's degree in informatics engineering from State Islamic University Syarif Hidayatullah Jakarta, Indonesia. She is currently pursuing the master's degree in electrical engineering with the Bandung Institute of Technology, Indonesia. Her current research interest includes digital transformation in education.

ATINA PUTRI received the bachelor's degree in informatics engineering from Telkom University, Indonesia, in 2015, and the master's degree from the Bandung Institute of Technology (ITB), Indonesia, in 2019, where she is currently pursuing the Ph.D. degree. She is an Academic Assistant and a Researcher. Her research interests include educational technology, serious games, and virtual reality.

YUSEP ROSMANSYAH received the bachelor's degree in electrical engineering from the Bandung Institute of Technology, Indonesia, in 1993, and the M.Sc. and Ph.D. degrees from the University of Surrey, U.K., in 1996 and 2003, respectively. He has been a Researcher and a Professor of smart multimedia processing with the School of Electrical Engineering and Informatics, Bandung Institute of Technology. His research interests include multimedia, educational technology, and cyber security.