International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 3, June 2025, pp. 2358~2368
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i3.30804

Technological leadership in industry 4.0 education: influence of digital transformation and ICT adoption

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Article Info

Article history:

Received Apr 7, 2024
Revised Oct 14, 2024
Accepted Oct 30, 2024

Keywords:

Digital transformation
Educational effectiveness
ICT integration
Industry 4.0 education model
Technological leadership

ABSTRACT

The objective of this article is a systematic investigation into the effectiveness of information and communication technologies (ICT) usage within the framework of the educational model "industry 4.0", focusing on the influence of digital transformation on technological leadership in educational institutions. The problem is insufficient technical equipment, uneven distribution of resources, and insufficient support for teachers. The solution lies in systematic innovative training and support for teachers, creating incentives to increase their motivation. The study employs an experimental research design, utilizing survey methods. The subjects of the research include six directors, six teachers, and 120 students from educational institutions in the United Arab Emirates (UAE) and the Russian Federation. According to the survey results, teachers have a positive attitude toward using ICT. A majority of teachers believe that the use of ICT has a positive impact on students' academic achievements. Responses to open-ended questions indicate a lack or uneven distribution of technical equipment, emphasizing the need for training and support for teachers. One teacher suggesting the "introduction of incentives and rewards" raises the issue of creating a reward system for teachers, which could affect their motivation. Regarding students' academic performance, the results show that students in educational institutions with active ICT integration demonstrate better results.

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1. INTRODUCTION

In the contemporary era, amid the industrial revolution and rapid technological changes in the education system, digital transformation is crucial, driving major changes in educational models and influencing the development of new teaching methods and leadership strategies [1], [2]. Digitalization stands as one of the megatrends of the century, possessing the potential for radical transformation across various industries and production technologies [3]. Based on this dynamic, the concept of "industry 4.0" has emerged, characterized by the digitization of the manufacturing sector. In this concept, sensors are integrated into nearly every element of production and manufacturing equipment, all-encompassing cyber-physical systems are present, and comprehensive data analysis is conducted [4]. Industry 4.0 has undertaken an innovative role in the realm of industrial information technologies, which are currently revolutionizing

production technology [5]. Industry 4.0 fundamentally represents a vision of the future conceived based on information and communication technologies (ICT) [5]. Manufacturing systems connected to ICT enhance efficiency and optimize operations, potentially altering how producers and industrial companies conduct business [5].

The importance of this research is motivated by the swift technological advancements, the widespread impact of the internet on all aspects of education, and the development of new digital competencies crucial for successful adaptation to the modern information society [6], [7]. Moreover, it is important to acknowledge that digital transformation during the recovery phase presents specific challenges, such as bridging the digital divide, guaranteeing universal access to technology, and maintaining the stability of the educational system in the face of continuous technological changes [7], [8]. The essence of the problem permeates various levels of contemporary education, where the integration of digital technologies and digital transformation necessitate a fresh perspective on the processes of learning and the roles of leaders in this context. Although research demonstrates a positive impact of digitalization on educational processes, a substantial portion of scholarly work focuses on the technical aspects of implementing ICT rather than analyzing their influence on pedagogical practices and technological leadership [5]. Prior studies have identified several issues related to the integration of ICT into educational processes, including a lack of access to necessary technologies, insufficient support from leadership, and inadequate digital competence among educators [6], [7]. Despite existing research, there remains a significant gap in understanding how digital transformation specifically affects technological leadership within educational institutions. There is a need for research that systematically examines not only the technical but also the managerial aspects of ICT implementation in education. This study aims to address this gap by exploring how educational leaders adapt to the challenges of digital transformation and how their leadership impacts the successful implementation of ICT.

ICT are becoming an integral part of the educational system [8], [9]. They have brought about changes in many spheres of people's lives, compelling educational institutions, administrators, and educators to reconsider their roles, teaching methods, and vision for the future [10]–[12]. This study provides a systematic analysis of the impact of ICT on technological leadership within educational institutions. The approach focuses on the effectiveness of ICT utilization by teachers in the educational process and compares students' academic performance in the context of ICT implementation versus traditional teaching methods. Data collection was conducted through surveys of teachers and students, as well as an assessment of students' academic performance, enabling the identification of key trends in ICT use and its impact on the educational process. The contribution of this work lies in the systematic analysis of the impact of ICT on technological leadership in education, identifying key trends, and practical aspects of implementing new technologies in the educational process. The novelty of the research is justified by the contemporary nature of the topic and the necessity to provide specific recommendations and strategies for educational leaders facing the challenges of digital transformation. The practical significance of this article is in offering a comprehensive evaluation of the effectiveness of ICT implementation and the impact of digital transformation on technological leadership within the context of the educational model “industry 4.0”. The survey results emphasize not only teachers' positive attitudes toward ICT usage but also reveal existing challenges such as a lack of support from leadership.

2. LITERATURE REVIEW

2.1. Industry 4.0

Industry 4.0 is a collective term that signifies breakthrough technologies and concepts for organizing the value chain, as well as a wave of disruptions and uncertainties, rooted in industrial transformation, revitalization, and development [13]. The fourth industrial revolution referred to as industry 4.0, is characterized by the “emergence of cyber-physical systems that offer entirely new possibilities for human-machine interaction” [10]. Researchers in previous studies suggest that these new capabilities are built upon the technologies and infrastructure established during the third industrial revolution, but industry 4.0 is characterized by novel methods of integrating technologies into society [8], [10], [14].

The term “industry 4.0” pays special attention to the merging of information technologies and biotechnologies. This definition facilitates the process of blurring the boundaries between the physical, digital, and biological worlds [10], [15]. The evolution towards industry 4.0 impacts almost every sphere of our daily lives, reshaping attitudes towards technology and transforming the nature and location of work [15]–[17]. This revolution starts from the leading positions of the industrial revolution but differs in that it selects technologies from international, physical, and biological realms [10]. An important note: evaluating industry 4.0 can be achieved by understanding the technologies that form its foundation. The author provided the following list of technologies: artificial intelligence (AI) and robotics, pervasive sensors, virtual and

augmented reality (AR), additive manufacturing, blockchain, and distributed ledger technologies, as well as advanced materials and nanomaterials, among many others [18].

2.2. Information computer technologies

Digital technologies have radically changed the field of education. Innovations such as smart devices, the internet of things (IoT), AI, AR, virtual reality (VR), blockchain, and a range of software applications are creating new opportunities for improving teaching and learning processes [19]. Digital learning can become a driving force for developing skills that contribute to the digital transformation of organizations [20]. According to the authors of the study, innovations are largely determined by business dynamics and leadership commitment, and to a significantly lesser extent by strategy. In the case of digital transformation, the role of IT departments and the services they provide is less significant [20].

In the works of various researchers, efforts of many countries are evident in integrating ICT into educational systems, aiming not only to provide access to technologies but also to create a learning context that aligns with the requirements of modern industry [21]–[23]. In recent years, education systems across various countries have significantly increased their investments in integrating ICT and have adapted their strategies and policies to prioritize ICT integration within their educational programs [22], [23]. This focus has led to challenges regarding the quality of teaching and learning with ICT, particularly in terms of understanding, adapting to, and developing education systems that align with current technological trends [24].

Research shows that despite significant investments in technology integration within schools, the anticipated outcomes have not been realized [21], [23]. The challenges became even more pronounced during the COVID-19 pandemic, which necessitated a shift to online education at all levels [25]. This rapid transition to online learning accelerated the adoption of digital technologies and highlighted issues related to the processes, nature, scale, and effectiveness of digitization in schools [26], [27]. Specifically, many schools faced challenges such as limited experience and low digital capacity, which exacerbated inequalities, disparities, and educational gaps [28], [29]. These observations highlight the urgent need for schools to analyze and learn from these experiences to improve their digital capabilities and overall level of digitization [6].

The digitization process offers opportunities for a significant overhaul of educational institutions and affects various aspects of their development [7], [8], [11]. However, it is a complex undertaking that involves more than just technical advancements in technology and infrastructure [12]. For successful digital transformation, schools need to strengthen their digital potential by developing a supportive "culture, policy, infrastructure, and digital literacy for both students and staff to facilitate the effective integration of technologies into teaching and learning" [6].

Literature gaps manifest in the limited number of studies dedicated to the systematic analysis of the impact of ICT on technological leadership in education. Many works focus on the technical aspects of technology implementation, sidelining issues of leadership and strategic management in the context of digital transformation. This creates a need for research oriented toward a systemic understanding of the interaction between technologies and the role of leaders in educational institutions. Limitations in existing research are partially attributed to the rapid changes in the technological landscape and the absence of generalized approaches to measuring the effectiveness of ICT in education. The novelty of the upcoming study lies in the development of a comprehensive methodological approach to examining the interaction of ICT and technological leadership in the educational environment, considering both technical and organizational aspects. This addresses existing gaps in the literature and contributes to understanding how to effectively shape educational strategies in the context of digital transformation.

2.3. Problem statement

Digital transformation brings significant changes to educational paradigms, requiring not only the updating of technical infrastructure but also a reconsideration of leadership strategies. The research hypothesis suggests that students in educational institutions with active ICT integration demonstrate a higher level of academic performance compared to students in institutions with less pronounced ICT integration. The aim of this article is a systematic investigation of the effectiveness of ICT in the context of the "industry 4.0" educational model, with an emphasis on the impact of digital transformation on technological leadership in educational institutions. Thus, the objectives of the study are: i) analysis of teachers' use of ICT in the educational process; and ii) analysis of student academic performance in the context of ICT implementation compared to traditional teaching methods.

3. METHOD

3.1. Study design

This study employed an experimental design incorporating elements of both quantitative and qualitative analysis. An experiment is a controlled and systematic investigation in which the researcher introduces changes to the environment to examine the impact of these changes on the studied object. Additionally, the survey method is utilized. Quantitative methods were utilized for the collection and analysis of numerical data, such as performance scores and survey results, while qualitative methods were employed to analyze open-ended responses from teachers and students regarding their attitudes toward the use of ICT.

3.2. Sampling

The subjects of the research include directors, teachers, and students from educational institutions in the United Arab Emirates (UAE) and the Russian Federation: United Arab Emirates University, Financial University under the Government of the Russian Federation, and I.M. Sechenov First Moscow State Medical University. As the study aims to examine the influence of technological leadership of directors on teachers' use of ICT and students' academic performance, the following subgroups of research participants were identified:

- Directors of educational institutions actively apply technological leadership strategies to implement ICT in the educational process, and directors follow more traditional approaches in managing the educational process without emphasis on technological leadership.
- Teachers working under the guidance of directors and using ICT in their practice, and teachers following traditional teaching methods without the use of ICT.
- Students from these educational institutions, as their academic performance, is a key indicator.

A total of six directors participated in the study (three in the traditional education direction and three in the ICT-enhanced education direction), along with 120 first-year students—20 from each educational institution. Among them, 68.2% were male students, and 31.8% were female students. The average age of the students was 20 years.

The study also involved six educators who developed and implemented the curriculum: three educators in the traditional education system and three educators in education with active ICT use. All educators had 7 years of work experience and held a master's degree. The educators covered the following subjects: mathematics, English language, and physics—two educators for each subject. All participants voluntarily took part in this research. Thus, the academic performance of students in both groups will be evaluated and compared in the context of the application of directors' technological leadership and teachers' use of ICT.

The sample size is adequate with regard to scientific standards and the research objectives [30]. The selected participants represent key groups corresponding to the primary areas of interest of the study. Considering the sample structure ensures adequate representation of various perspectives and allows for a sufficiently objective assessment of the impact of technological leadership on ICT utilization and students' academic achievements.

3.3. Procedure

The training spanned 3 months, from March to May. Participants were divided into two groups: control and experimental, with 60 students in each group (10 students from each educational institution). Both groups of students followed the same school curriculum, with the control group (CG) employing traditional teaching methods, while the experimental group (EG) utilized ICT. Instruction was conducted by educators according to their disciplines and the semester schedule.

Table 1 illustrates key differences between traditional and innovative education in the context of the "industry 4.0" model. Innovative education focuses on the active use of modern technologies, interactive teaching methods, and a variety of resources and tools to improve the effectiveness of the educational process. Teachers applied all these resources in their subject teaching.

3.4. Data collection

The teacher survey, as shown in Table 2, was conducted online through the Google Forms service. The service accepted only fully completed surveys. The questionnaire included 6 Likert-type questions, 3 questions with various response options, and 1 open-ended question. A comparison of student academic performance in educational institutions with active ICT integration (EG) and institutions where this integration is less pronounced (CG) was conducted through examinations in the studied subjects.

3.5. Research tools

To measure the degree of integration of ICT into the educational process under the guidance of technological leaders, the following instruments were utilized: teacher survey, comprising questions about

the frequency of ICT usage in the teaching process, satisfaction with the technologies used, and assessment of support from leadership. The reliability of the questionnaire was assessed using the correlation coefficient, which yielded a value of 0.75, confirming the reliability of the method. To verify the validity of the methodology, the concordance coefficient was employed, showing a value no lower than 0.6, indicating a high level of validity for the method. The analysis of the teachers' survey data was conducted using quantitative methods, including the calculation of the percentage ratio of positive and negative responses to each question, as well as the computation of standard deviation (SD). This method aids in assessing how uniformly or diversely teachers use ICT in different aspects of the educational process. Percentages provide a clear and easily understandable numerical representation of the integration of ICT into the teaching process.

An analysis of grade data for subject exams was carried out between the two groups of students. The T-test was used to compare the average scores between the groups. This helped determine whether there were statistically significant differences between the groups. SD were also calculated to assess the variability of scores within each group.

Table 1. Comparison of characteristics of traditional and innovative learning in the context of the "industry 4.0" model applied by educators in teaching

Group	CG	EG
Type of learning	Traditional	Innovative
Learning model	Traditional	Educational model "industry 4.0" - active use of ICT
Educational materials	Textbooks, didactic materials	Interactive e-textbooks, online platforms, multimedia resources
Teaching methods	Lectures, group sessions, practical work, seminars	Problem-oriented projects, case methods, and learning using virtual and AR
ICT tools	Computers, projectors, electronic boards	Interactive boards, tablets, cloud technologies, online collaboration, 3D modeling
Interaction	Limited interaction, traditional forms of communication	Collaborative work, online forums and chats for communication, virtual conferences
Assessment	Traditional methods (tests, assessments)	Use of online testing, analysis of project work, performance diagrams
Teacher support	Infrequent updating of professional skills	Frequent training, knowledge exchange, support from ICT specialists
Student roles	Passive participation, emphasis on knowledge transfer by the teacher	Active participation, independent research, group collaboration
Teacher-student support and feedback	Limited support, mainly in the classroom	Regular consultations, online forums for discussion, instant feedback on assignments
Teacher professional development	Traditional training and seminars.	Participation in webinars, online courses, and experience exchange with colleagues through virtual communities.

Table 2. Questionnaire for teachers to understand the role of ICT in teaching and the impact of leadership

No.	Question	Answer options
1.	Rate your level of access to ICT in the educational process.	i) excellent; ii) good; iii) satisfactory; and iv) poor
2.	Do you think the level of support from the leadership satisfies your use of ICT?	i) yes, completely; ii) more yes than no; iii) more no than yes; and iv) no, not at all satisfied
3.	How does the use of ICT in your teaching impact your teaching methods and strategies?	i) positive; ii) neutral; iii) negative; and iv) I don't notice any impact
4.	Are there any difficulties or limitations in using ICT in your teaching practice?	i) no difficulties; ii) minor difficulties; iii) neutral; and iv) difficult
5.	What is your opinion on the impact of using ICT on students' academic achievements?	i) positive; ii) neutral; iii) negative; and iv) hard to say
6.	Do you believe that integrating ICT into the educational process enhances your leadership skills?	i) yes, completely; ii) to some extent; iii) not sure; and iv) no, not at all
7.	What specific ICT resources are provided to you for educational purposes?	i) computers and laptops; ii) interactive whiteboards; iii) educational software; and iv) online resources and platforms
8.	How regularly do you use ICT in your teaching activities?	i) daily; ii) several times a week; iii) rarely; and iv) almost never
9.	What ICT training and support does your leadership provide?	i) regular training and seminars; ii) individual consultations; iii) access to educational resources; and iv) no support
10.	What improvements would you suggest in the support and use of ICT in your school/educational institution?	Open question

3.6. Ethical issues

Adhering to ethical principles plays a crucial role in ensuring the ethicality and reliability of the conducted research, as well as in protecting the interests and safety of all participants. Therefore, during the data collection process, all participants were informed about the research objectives, their rights, and

measures to protect confidential information. Participation in the experiment was entirely voluntary, and each participant provided written consent to take part.

3.7. Research limitations

The study was conducted only in educational institutions in two countries—the UAE and Russia. The results may not fully reflect the diversity of educational systems in other regions. The sample size of directors, teachers, and students is relatively small (six directors, six teachers, 120 students). This may limit the generalization of results to larger populations. The use of surveys to assess teachers may subject the results to participants' subjective perceptions, and subjective assessments may be prone to bias. The three-month training period may be insufficient for a comprehensive understanding of the long-term effects of ICT integration into the educational process.

4. RESULTS

4.1. Assessment of teacher surveys

Table 3 illustrates the percentage distribution of teachers' responses to Likert-type questionnaire questions. Regarding the first question in the table, it is evident that teachers are evenly distributed concerning their access to ICT. The variation is quite high, indicating diversity in situations across educational institutions: three educators employed a traditional method without active ICT access, while the remaining three actively utilized ICT in the educational process. Concerning question 2, the majority of teachers—83%—are satisfied with the level of support from leadership in the utilization of ICT.

Table 3. Teachers' responses to the questionnaire

	Question	Positive answer (%)	Negative answer (%)	SD
1.	Evaluate your level of access to ICT in the educational process.	50	50	2.90
2.	Do you believe that the level of support from leadership satisfies you in the use of ICT?	83	17	2.95
3.	How does the use of ICT in your teaching activities impact your teaching methods and strategies?	66.4	33.6	2.07
4.	Are there any difficulties or constraints when using ICT in your teaching practice?	83	17	2.13
5.	What is your opinion on the influence of ICT usage on the academic achievements of students?	66.4	33.6	2.89
6.	Do you believe that the integration of ICT into the educational process enhances your leadership skills?	83	17	2.21

Number of educators: six people

Thus, 66.4% of teachers positively assess the impact of ICT on their teaching methods, suggesting that technology integration brings positive changes to the educational process. Additionally, 83% of teachers encounter difficulties or constraints when using ICT, necessitating an analysis of these issues and the provision of additional support. The majority of teachers believe that ICT usage positively influences the academic achievements of students.

Totally 83% of teachers consider that the integration of ICT into the educational process contributes to enhancing their leadership skills. Considering these findings, it can be concluded that, overall, teachers have a positive attitude toward ICT usage, but they face challenges in obtaining support from leadership. For responses to the subsequent questionnaire questions with various response options, the following results were obtained: for question 7, "What specific ICT resources are provided to you for educational purposes," 50% of teachers selected only computers/laptops and interactive whiteboards, while the remaining 50% of teachers chose all four response options: computers and laptops, interactive whiteboards, educational software, online resources, and platforms. This distribution suggests that likely, all four response options were chosen by teachers who were trained using ICT.

In response to question 8, "How regularly do you use ICT in your teaching activities," the obtained responses were as: 83% daily, 17% rarely. For question 9, "What training and support in ICT does your leadership provide," 50% of teachers responded without support, while the remaining 50% reported regular training and seminars, along with access to educational resources. Question 10, "What improvements would you suggest in the support and utilization of ICT in your school/institution," was of an open-ended nature. Some teachers responded: "Enhancing the accessibility of necessary technical resources, such as computers, interactive whiteboards, software, and online resources," "Conducting regular training and seminars for teachers on the integration of ICT into the educational process," "Introducing incentives and rewards for

teachers actively using ICT in education." Consequently, these responses indicate a lack or uneven distribution of technical equipment, emphasizing the need for systematic training and support for teachers.

The teacher proposing "the introduction of incentives and rewards" raises the question of establishing a reward system for teachers, which may impact their motivation. The responses suggested by teachers underscore the importance of improving resource accessibility and training to enhance the quality of education through ICT. These responses elucidate specific challenges and expectations teachers have regarding support and ICT utilization in the educational process, as well as their aspirations for improving the current situation.

4.2. Assessment of students' academic performance

Table 4 presents the results of examinations for both groups of students after the completion of the training. The SD indicates a wider range of grades in the CG, suggesting a broader spectrum of student success. The t-test and P-value analysis reveal that, for all subjects, the t-critical value significantly deviates from zero, and the P-value is less than the commonly accepted significance level of 0.05. This indicates statistically significant differences in academic performance between the groups.

Table 4. Results of examinations for two groups of students after training

Group	Training type	Average score			Standard deviation	t-criteria	P-value
		Mathematics	English language	Physics			
CG	Traditional	79.5	78.2	81.1	6.3	2.1	0.031
EG	Innovative	88.1	87.8	86.3	5.7	3.8	0.005

Students in educational institutions with active integration of ICT in the EG demonstrate superior performance across all subjects. This supports the hypothesis that the integration of ICT into the educational process contributes to improved student academic achievement. The differences in academic performance are statistically significant for all subjects, confirming that more intensive use of ICT is associated with better academic performance. The results affirm the importance of integrating ICT into the educational process.

Consequently, one can conclude that the innovative teaching method employed in the EG is more effective. Students in the EG achieved higher results compared to the traditional teaching method (CG). The application of innovative teaching methods in the context of the "industry 4.0" educational model positively impacts student outcomes and brings educators using ICT in teaching closer to technological leadership in educational institutions. This could serve as a basis for recommending the implementation of innovative methods in educational programs.

5. DISCUSSION

A significant number of stakeholders in the field of education express concern about digitization in higher education [31]. Access to digital skills becomes increasingly critical in various domains, especially in the workplace. One of the authors suggests that information management studies should pay more attention to students, considering their increasingly digital daily lives and foundational education, viewing them as key factors [31]. One conducted study aims to explore initiatives related to industry 4.0 through a comprehensive literature review to assess the extent of their implementation in different regions [32]. Survey results indicated that 117 industry 4.0 initiatives have been launched in 56 countries worldwide, covering five regions: Europe (37%), North America (28%), Asia and Oceania (17%), Latin America and the Caribbean (10%), as well as the Middle East and Africa (8%). The global share is estimated at 25%, indicating significant differences among countries in the race to adopt industry 4.0. The results of another study also indicate that digital transformation significantly impacts the attitudes, psychology, and work-related factors of employees in industry 4.0 [33].

The development of ICT allows for the integration of a broader range of informational services into educational programs. The results of one study indicate that the integration of ICT is highly effective for both educators and students [34]. The data suggest that teacher training using ICT tools and resources is a key factor in the success of technology-based teaching and learning. Additionally, it was found that professional development programs for teachers also play a crucial role in enhancing the quality of student education. Another study revealed that the majority of teachers perceive ICT integration positively due to its effectiveness. However, it was also reported that lack of internet access, insufficient technical support from schools, and limited ICT knowledge and training deterred teachers from utilizing ICT [35]. Another study aims to assess educators' perspectives on the use of ICT in teaching [36]. The study employed a mixed

research method, including both experimental measurement and qualitative analysis. A total of 58 teachers participated in the study. The results indicated that it is important for educators to embrace technology, closely monitor its advancements, and demonstrate a positive attitude towards it to utilize emerging technologies in the classroom effectively. Consistent with this work, our findings revealed that teachers generally have a positive attitude towards the use of ICT, with 83% of positive responses regarding support from leadership and 66.4% regarding its impact on teaching methods. Our results also indicate the presence of challenges and limitations in the use of ICT, aligning with the conclusions of other studies.

One study aimed to analyze higher education instructors' attitudes towards ICT [37]. A non-experimental research design was employed using a survey method, and descriptive and logical analyses were conducted through a multiple linear regression (MLR) model. The results indicated that instructors hold a moderate attitude toward the use of ICT. Another study indicates that a primary institutional factor and barrier is the presence of specific national strategies for industry 4.0 education and a mindset that opposes the reforms associated with industry 4.0 education [38]. Our study showed a more positive attitude towards ICT among instructors but also revealed the presence of difficulties and limitations. These challenges may be similar to those described in the previous study, particularly concerning the lack of tools and support.

Another study aimed to explore higher education instructors' attitudes toward the implementation of ICT in English language teaching [39]. Data were gathered through a questionnaire distributed to 81 teachers and analyzed using SPSS. The findings revealed that university instructors had a positive attitude towards integrating ICT into English language teaching. They perceived ICT as an effective tool for facilitating teaching and learning, motivating students, and developing all language skills. However, the actual use of such technologies in the classroom was not at the desired level. Teachers who did not integrate ICT into their classes attributed this to various factors, such as a lack of ICT tools in their departments, absence of internet access, and insufficient computer competence and training. In our study, teachers also exhibited a positive attitude towards ICT but highlighted the presence of difficulties and limitations. Our findings align with those of other studies, which emphasize the need for sufficient resources and training to facilitate more widespread ICT implementation.

Another study aimed to investigate how young students self-assess their digital competence [40]. Utilizing a non-experimental, descriptive quantitative methodology, data were collected through an electronic survey. The main findings indicated that students rated their attitude toward ICT as positive, their engagement with ICT as moderate, and their knowledge of ICT as limited. Although the study did not specifically evaluate students' self-assessment of their digital competence, the results indicated that students who integrated ICT into the learning process achieved higher academic performance. These findings may suggest an enhancement in their digital skills through active use of technology in education. Another article's results indicate that increased use of ICT in a school community does not have a positive impact on mathematics and reading achievement, while a positive effect is observed on science learning outcomes. These results suggest that the impact of ICT on educational outcomes depends on the subject matter and the type of technology used [22]. In this study, students in the EG, where ICT was actively utilized, achieved higher results compared to the traditional teaching method employed in the CG. The application of innovative teaching methods within the educational framework of "industry 4.0" positively influences student outcomes and brings educators using ICT in teaching closer to technological leadership in educational institutions.

Regarding methodological contributions, this study is based on the use of a mixed-methods approach, which includes both quantitative and qualitative analysis, enabling a comprehensive exploration of attitudes towards ICT in higher education. This approach aligns with previous research that has employed similar methods to examine the impact of ICT on academic outcomes [36], [37]. Thus, the contribution lies in expanding the methodological framework for research aimed at evaluating ICT within the context of higher education. The practical contribution of this study is its demonstration of the importance of using ICT not only as an ancillary tool but also as a primary means of enhancing the educational process. This research may be utilized to further develop teacher training programs and to inform educational policies in the realm of digitalization.

6. CONCLUSION

Based on the survey results, teachers generally have a positive attitude toward the use of ICT; however, they encounter difficulties in obtaining support from the leadership. Moreover, the majority of teachers believe that the use of ICT has a positive impact on students' academic achievements. Responses to the open-ended question from teachers indicate a shortage or uneven distribution of technical equipment, highlighting the need for systematic training and support for educators. The teacher proposing the "introduction of incentives and rewards" raises the issue of establishing a reward system for educators, which could influence their motivation. Regarding student academic performance, the results indicate that students in educational institutions with active integration of ICT demonstrate better results across all subjects.

This supports the hypothesis that the integration of ICT into the educational process contributes to improved student performance. The differences in academic performance are statistically significant for all subjects, confirming that more intensive use of ICT is associated with better academic achievement.

Research proposals focus on conducting studies that explore the impact of specific applications or educational platforms on learning outcomes, examining the influence of ICT across different countries and educational contexts to gain a more comprehensive understanding of global trends, and carrying out longitudinal studies to assess the durability of results and the long-term effects of ICT use in education. Teachers can use the results to better comprehend the influence of ICT on their teaching methodologies, while students can evaluate how technology usage affects their academic performance. The practical implications of these findings for educational practice and policy include the development of resource provision strategies to ensure an equitable distribution of technical resources across all educational institutions; the implementation of systematic training and support programs for teachers to enhance their competence in using ICT; the creation of motivational programs for teachers to encourage their active engagement with ICT; and the use of research results to inform strategies and policies aimed at integrating ICT into the educational process to improve students' academic performance.

FUNDING INFORMATION

The research received no funding.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
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Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
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CONFLICT OF INTEREST STATEMENT

Authors declare that they have no conflict of interest.

INFORMED CONSENT

Participation in the experiment was entirely voluntary, and each participant provided written consent to take part.

ETHICAL APPROVAL

The authors declare that the work is written with due consideration of ethical standards. The study was conducted in accordance with the ethical principles approved by the Ethics Committee of Sharjah Education Academy

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

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