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Educational Leadership's Knowledge of the Fourth Industrial Revolution: Perceptions and Interpretations in the Contemporary School

Konstantinos Zogopoulos [1], Georgios Panagiotopoulos [2]
[1](PhD Candidate Department, of History-Archaeology University of Patras, Greece)
[2](Professor, Department of History-Archaeology, University of Patras, Greece)

Abstract:
Background*: The Fourth Industrial Revolution has brought profound changes to society and education in particular, with the introduction of technologies such as artificial intelligence, robotics and virtual reality. The role of school principals is now critical, as they are called upon to guide schools within this new digital environment. However, questions remain as to whether education leaders themselves understand these technologies and are ready to manage the changes that they entail. The present study explores the knowledge, attitudes and readiness of principals in relation to the 4th Industrial Revolution, both through their own narratives and from the perceptions of the teachers who work with them.*
Materials and Methods*: The study follows a mixed methodological approach. Initially, a quantitative survey was carried out through a questionnaire, in which 1,359 Primary and Secondary Education teachers from all over Greece participated. The questionnaire focused on their knowledge and perceptions of the technologies of the 4th Industrial Revolution and their assessment of the relative competence of the principals. Qualitative research was conducted with semi-structured interviews of 20 school principals, focusing on their own views, knowledge and attitudes. The analysis of the data was done through statistical tools for the quantitative phase and a thematic analysis for the qualitative phase, with the aim of triangulating the findings.*
Results*: Teachers generally rated principals' knowledge of key technologies of the 4th Industrial Revolution, particularly with regard to artificial intelligence, cybersecurity and the use of technologies in school administration. Leadership readiness was recorded at moderate to positive levels, with a high percentage recognizing the importance of continuous learning and adaptation. Although managers show a positive attitude and willingness to integrate new technologies, many feel inadequately prepared and point to a lack of training, time and technological infrastructure as key obstacles. Nevertheless, they undertake personal initiatives for self-education and seek to act as catalysts for change in their schools.*
Conclusion: *The study highlighted an educational leadership that is on a positive trajectory of adaptation to the demands of the 4th Industrial Revolution. Managers have basic knowledge and recognize the importance of digital transformation, while also expressing a realistic awareness of the challenges. Although they do not feel fully prepared, they demonstrate an intention for development, self-improvement and visionary leadership. Supporting them with appropriate training and infrastructure strengthening is a necessary prerequisite for them to be able to effectively guide the school towards the future of Education 4.0.*
Key Word*: Educational Leadership, Fourth Industrial Revolution, Knowledge, Teachers, Education 4.0*

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I. Introduction

The Fourth Industrial Revolution is characterized by rapid technological changes that are transforming all sectors, including education. Concepts such as "Education 4.0" describe an educational reality where cutting-edge technologies (such as artificial intelligence, robotics, the Internet of Things and big data) are integrated into the learning process, creating more personalized and dynamic learning environments. In this context, the role of educational leadership is critical. School leaders are called upon to lead the digital transformation of schools, acting as catalysts for the uptake of innovations and ensuring that technology is harnessed for the benefit of learning[9].

The very concept of leadership is multidimensional and has been extensively studied. Modern approaches describe it as a dynamic phenomenon that emerges from the interaction of leaders, followers and the environment[25]. However, despite the intense research interest, there is no one-size-fits-all definition[22]. In the literature there are hundreds of definitions (more than 1,500 have been recorded) which share some common elements. For example, 38 gathered more than 350 definitions, pointing out that leadership is linked to a process

of influencing others to achieve desired goals. On the contrary, management is concerned with maintaining the organisational structures of the organisation. Correspondingly, 46 described leadership as a process of guiding and influencing to achieve goals. Younger scholars focus particularly on the role of vision and change. For example, 34 describe leadership as the art of mobilizing others for a common goal, emphasizing the importance of inspiration exercised by the leader. At the same time, leadership is considered to be strongly influenced by the context and requires adaptability to the circumstances[51]. According to [24], modern effective leadership emphasizes cooperation and the distribution of power, keeping human contact at the center. In addition, it is a behavioral process in which the leader, through communication and collaboration, positively influences his followers and acts as a catalyst for innovation within the organization[31].

Digital educational leadership is emerging as a new paradigm of school management in the 21st century. It is not just about the use of digital tools, but it is a holistic approach to management through technology so that the school can adapt to modern needs. O[52] identified five key dimensions that a digital leader must have, including a deep understanding of the learning process and change; the ability to think creatively and innovatively and a clear vision for digital transformation. In addition, a digital leader needs a willingness to continuously learn by applying new knowledge, as well as the ability to make informed decisions based on an extensive understanding of data. Similarly, the [50] broaden the concept, defining digital leadership as a set of skills and attributes that allow the leader to influence and motivate others to improve performance. A study of [26] highlighted five critical competence axes for leaders in technologically advanced environments: clear digital vision, sufficient digital knowledge, ability to adapt quickly after failures, team empowerment and effective management of multicultural teams. Respectively, the [36] describe multiple roles that the leader must take on for a successful digital transition – among others, the role of strategic planner for the digital age, digital culture builder and digital infrastructure architect. At the level of educational practice, leaders are invited to develop their own digital skills and those of their staff, ensuring that the transition to the new digital culture will be smooth[17]. Overall, the role of educational leadership in the digital age is multidimensional. It is not limited to the management of technological means. Rather, it involves the continuous professional development of teachers, the creation of a culture that embraces innovation and technology, and the formation of a climate of cooperation between teachers, students and parents.

The integration of cutting-edge technologies in education requires targeted strategic planning and substantial support of school leadership by the state and institutions – especially in the Greek reality where possible shortages in resources and infrastructure can be limiting factors. Modern managers need to understand technological developments, encourage continuous training of their teachers, and design learning environments that effectively integrate innovations, fostering collaboration and individualized learning[20]. In addition, the use of digital tools is not limited to teaching, but also affects the administrative functions of the school. For example, the introduction of digital management systems facilitates access to data and allows leaders to make informed decisions, thus enhancing school efficiency[1]. In other words, educational leadership in the 4th Industrial Revolution can be a key lever for innovation and improvement of school units. When leaders adopt new technologies and digital systems, they upgrade the operation of their organizations and can improve learning outcomes. For example, it has been observed that in countries such as Malaysia the active use of digital tools by school leadership was associated with enhanced student performance[20]. Despite the significant potential offered by technology, the transition to digital education also comes with notable challenges. Many schools face shortcomings in digital infrastructure, while some teaching staff may resist changes that disrupt established practices. In addition, the inadequate continuous training of teachers in new technologies is a serious obstacle to the realization of the vision of Education 4.0[42].

In Greece in particular, the absence of a clear and comprehensive strategic plan for the digital transformation of education can undermine digital modernization efforts. Without proper coordination and support, even the most well-intentioned initiatives to adopt new technologies in schools risk failing. Overcoming these difficulties requires a comprehensive action plan. This includes upgrading technological infrastructure, continuously investing in teacher vocational training, as well as creating a school environment that fosters creativity, innovation and collaboration[12].

At the same time, it is proposed to adopt a non-centralized, collaborative approach to leadership[18]. This is linked to the concept of distributed leadership, according to which leadership is not limited to management but is disseminated to all members of the educational community. This model recognizes that leadership can be shared among many, regardless of one's formal position; strengthening the collective effort[11]. Research shows that distributed leadership enhances staff engagement and can contribute to improved educational outcomes through teacher empowerment[23, 28]. Of course, the transition from a traditionally hierarchical structure to a more horizontal model is not without difficulties. An unclear distribution of responsibilities can slow down decision-making and create confusion, especially in organizations with a strong hierarchical culture[10, 29]. Therefore, successful change management requires leaders not only technical knowledge, but also developed problem-solving skills; fostering innovation and adapting to constantly new data[49].

In conclusion, educational leadership in the era of the 4th Industrial Revolution is the driving force that can transform the school and lead it into the digital future. Today's school leaders generally have a positive attitude towards technological innovation and understand its value in improving learning. At the same time, they recognize the need for continuous learning and personal development in order to meet the challenges of the new era. Continuous teacher training, appropriate support from the state and the cultivation of a school culture that encourages innovation are key prerequisites for principals to bridge the gap between the present and the digital future of education. Modern studies underline that the continued emphasis on learning and innovation on the part of leadership is a decisive factor for the success of educational organizations in the digital age[43].

Based on this theoretical framework, a key question examined in the present research study concerns the level of knowledge of principals about the technologies of the 4th Industrial Revolution, according to their self-assessments and teachers' perceptions. Thus, the research objectives are formulated as follows:

- What are the teachers' perceptions of the level of knowledge of principals regarding the Fourth Industrial Revolution?
- How do the directors themselves describe their knowledge of the Fourth Industrial Revolution?

II. Material And Methods

The present research study, which was conducted in the context of the preparation of the doctoral thesis, aimed to investigate the perceptions of Teachers and Directors of Primary and Secondary Education in Greece for Knowledge and Understanding regarding the fourth industrial revolution. The investigation had two phases. A quantitative and a qualitative one: a) For the conduct of the quantitative research, the method of random sampling was used. The questionnaire was created through Google Form and sent to the Directorates of school units (Primary, Junior High and High Schools) from all over Greece via email. The data collection for the quantitative research took place in the period February-March 2025. b) The qualitative research was conducted using a semi-structured interview with two main questions during the period mid-April to mid-May 2025. The Zoom video conferencing platform was used for the interviews.

Sample: 1359 teachers of Primary Education (PE) and Secondary Education (DE) who responded and completed the questionnaire were finally sampled from the survey. For the qualitative survey, the method of intended sampling of Principals from all over Greece was used. The sample of the survey consisted of a total of 20 Directors of Primary, Secondary and Lyceum Schools from all over Greece

The questionnaire: This research was conducted in the context of the preparation of the doctoral thesis. The research includes two phases: a) A quantitative one, using a two-part self-report questionnaire (Demographic-Professional Characteristics and the Knowledge Module for the 4th Industrial Revolution), which contains 13 closed-ended questions and the respondents were asked to answer a six-step Likert scale (1=I strongly disagree, 2=I disagree a lot, 3=I disagree a little, 4=I agree a little, 5=I agree a lot, 6=I agree completely). For the qualitative survey, a semi-structured questionnaire was used as a reference point with 20 key questions where the Directors of the sample were asked to answer. The questions were indicative and there was the possibility of additional questions for clarification or in-depth in-depth search.

Data analysis: The present research study followed a mixed methodological approach, combining quantitative and qualitative data collection techniques in a single research project. A central element of the mixed approach is the triangulation of data, i.e. the use of multiple sources or methods in order to cross-check and verify the findings. Initially, in quantitative research, the data obtained from the 1359 primary school teachers and Secondary Education from all over Greece were analyzed using the statistical software SPSS 29.0 for Windows. The reliability of the internal consistency of the variables of the questionnaire (Table 1) is high (0.930>0.70). A check of the normal distribution of variables was then performed with the Kolmogorov-Smirnov test, which showed a normal distribution (>0.05). The data was analyzed using descriptive statistics (Tables, Percentages, Mean Values, Standard Deviations). Then, in the second phase of the qualitative research, based on the responses from 20 interviews with school principals from all over Greece, an inductive thematic analysis was carried out for the thematic axis "Knowledge and attitudes for the 4th Industrial Revolution". The analysis stages[7, 47] were followed, with coding and emergence of topics from the data. Then triangulation followed for the cross-referencing and comparison of the findings from the two research phases

Table 1: Reliability check

	N of Items	Cronbach's Alpha
Knowledge of the 4th Industrial Revolution	13	0,930

III. Result

Quantitative Research

Table 2 *Percentage Distribution, Average Value and Standard Knowledge and Understanding Deviation*

of the 4th Industrial Revolution. As far as the Knowledge about the 4th Industrial Revolution of the Directors is concerned, according to the perceptions of the participating teachers of PE and DE, the questions are organized in two dimensions: a) Knowledge and understanding of the 4th Industrial Revolution, b) Leadership readiness and change management). The analysis is based on the rates of agreement and disagreement, and is accompanied by the mean value (MT) and the standard deviation (TA). MT is calculated based on the Likert scale (1=Strongly disagree, 2=Disagree a lot, 3=Disagree a little, 4=Agree a little, 5=Agree a lot, 6=Agree completely).

a) Knowledge and understanding of the 4th Industrial Revolution. According to the perceptions of the respondents, the manager seems to have sufficient knowledge of the fourth industrial revolution and its key technologies. 75.7% agreed to some extent, with the average value recorded at (MT=4.17 TA=0.038). The degree of agreement is characterized as moderate to fairly high. Respondents also estimate that the director understands how the fourth industrial revolution affects society and education. The overall percentage of positive responses reaches 77.8%. The average value of this estimate is (MT=4.28 TA=0.037), which corresponds to a large degree of agreement. The picture is similar for the understanding of technologies such as artificial intelligence, the Internet of Things and robotics. 76% of respondents agree that principals understand the impact of these technologies on school operations. The average value is set at (MT=3.92 TA=0.039), with the agreement level being moderate to high. The picture is more cautious when it comes to understanding the role of blockchain and big data. The overall percentage of agreement amounts to 62.6%. The average value is (MT=4.36 TA=0.039), which, although relatively high, is accompanied by a greater dispersion in responses, which reflects less unanimity. 69.8% of respondents believe that the manager understands the potential of augmented and virtual reality to improve the learning experience. The average value of this estimate is (MT=3.86 TA=0.042), which indicates a moderate level of agreement. When it comes to how the fourth industrial revolution affects the role of principals and the operation of schools, 75.1% of respondents agree. The average value is at (MT=4.07 TA=0.039), characteristic of a relatively positive stance. Even higher is the agreement that new technologies contribute to the administrative improvement of the school. 81.5% believe that managers recognize this. The average value is (MT=4.01 TA=0.039), with the general trend being positive. The highest acceptance is recorded in the perception of the importance of cybersecurity. 85.2% of respondents agree that the principal is aware of the importance of protecting the data of students and the school. The average value is (MT=4.29 TA=0.038), reflecting a high level of agreement and low divergence. The overall results show that respondents have a positive view of managers' knowledge of the technological developments of the fourth industrial revolution. Despite the small variations per thematic area, the general attitude is reinforcing and recognises the existence of relative competence, mainly in areas related to the operation and safety of the school.

Table 2: Percentage Distribution, Average Value, and Standard Knowledge and Comprehension Deviation of the 4th Industrial Revolution

Statements *The Director:*	I totally disagree	I disagree quite a bit	I disagree a bit	I agree a little bit	I agree quite a bit	Agree	MT*	THE
1. He has sufficient knowledge of the 4th Industrial Revolution and its basic technologies.	6,2	9,5	8,6	28,3	32,2	15,2	4,17	0,038
2. Understand how the 4th Industrial Revolution affects society and education.	5,3	9,3	7,7	24,1	37,1	16,6	4,28	0,037
4. Understands that technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Robotics are influencing the way schools operate.	6,2	7,1	10,8	20,1	32,5	23,4	3,92	0,039
5. Understands that Blockchain and Big Data will play a crucial role in data management and decision-making in school.	10,4	11,5	15,5	22,7	24,7	15,2	4,36	0,039
6. Understands that Augmented (AR) and Virtual Reality (VR) technologies can improve the learning experience.	6,4	11	12,8	25,2	27,8	16,8	3,86	0,042
8. Recognizes that the 4th Industrial Revolution affects the way schools operate and the role of principals.	5,1	8,6	11,3	21,9	33,3	19,9	4,07	0,039
9. Considers that new technologies help to improve the administrative management of the school.	2,6	7,7	8,2	19,4	35,8	26,3	4,01	0,039
11. Knows that cybersecurity is important for the protection of student and school data	2,6	3,3	8,8	13	32,9	39,3	4,29	0,038

*Note. *(1=I disagree completely, 2=I disagree a lot, 3=I disagree a little, 4=I agree a little, 5=I agree a lot, 6=I agree completely)*

Table 3 *Percentage Distribution, Average Value, and Standard Divergence of Leadership Readiness and Change Management.* b) Leadership readiness and change management. As can be seen from the participants' perceptions, the manager is to some extent prepared to manage the changes brought about by the fourth industrial revolution (Table). 67.6% agree at some level. The average value of this estimate is (MT=3.92 TA=0.039). The degree of agreement is characterized as moderate to positive. 67.7% of respondents believe that the manager is aware of the cognitive and social skills necessary to adapt to the new conditions of the time. The average value is set at (MT=4.01 TA=0.039), with the agreement level moving towards positive acceptance. There is a greater consensus on the view that changes in the school workplace require new educational tools and methods. 83% of respondents agree with this position. The average value is high (MT=4.59 TA=0.036), which shows a strong acceptance of the need for leadership support and innovation in teaching. Even higher is the appreciation for the importance of continuous learning and training. 89.8% agree that the manager understands this value. The average value reaches (MT=4.98 TA=0.033), reflecting a very high level of agreement and limited variation in responses. Finally, 88.1% of respondents believe that the manager must have leadership skills that adapt to and meet the demands of the fourth industrial revolution. The average value in this case is equally high (MT=4.93 TA=0.035), which reinforces the image of a modern and flexible leadership.

Table 3: Percentage Distribution, Mean Value and Standard Deviation
Leadership Preparedness and Change Management

Statements *The Director*:	I totally disagree	I disagree quite a bit	I disagree a bit	I agree a little bit	I agree quite a bit	Agree	MT*	THE
3. He/she is adequately prepared to manage the changes brought about by the 4th Industrial Revolution.	8,6	9,7	14,1	29,4	24,7	13,5	3,92	0,039
7. Knows the cognitive and social skills required to adapt to the new conditions brought about by the 4th Industrial Revolution.	7,1	10,8	14,3	25,6	26	16,1	4,01	0,039
10. Considers that changes in the school workplace require new educational tools and teaching methods with the support of educational leadership	4,2	5,1	7,7	19,9	36,6	26,5	4,59	0,036
12. Understands the value and importance of continuous learning and training.	2,9	3,1	4,2	14,1	34	41,7	4,98	0,033
13. Must have leadership skills that adapt and meet the requirements of the 4th Industrial Revolution.	3,3	4,2	4,4	13,5	33,8	40,8	4,93	0,035

The overall results for Knowledge for the 4th Industrial Revolution show that respondents have a positive view of managers' knowledge of the technological developments of the Fourth Industrial Revolution. Despite the small variations per thematic area, the general attitude is reinforcing and recognises the existence of relative competence, mainly in areas related to the operation and safety of the school. Managers seem to be recognized by respondents as key factors of leadership adaptation to the changes brought about by the new technological era. Special emphasis is placed on the need for continuous learning and skills development, but also on guiding the school community with vision and adaptability.

Qualitative Research

Table 4 *Managers' perceptions of the 4th Industrial Revolution.* The analysis highlighted three main themes: (1) How the participants perceive the term "4th Industrial Revolution", (2) what technologies they consider important for education, and (3) how prepared they feel for the changes it brings. Each topic includes sub-topics and properties, which are presented with corresponding examples from the interviews.

The first main issue concerns the way managers perceive the concept of the 4th Industrial Revolution. Most of them directly linked it to the evolution of technology, while some also pointed out broader social dimensions or expressed ignorance of the term.

Sub-topic 1.1: Emphasis on technological innovation (Artificial Intelligence, robotics). Many participants perceive the 4th IR primarily as a rapid technological development focusing on artificial intelligence and automation. Characteristically, one director mentioned that she associates it with the invasion of AI everywhere, which can be very useful in various areas. Others spoke of automated systems and robotization

as key elements of the new era. For example, one director defined the 4th IR "as automation and robotization" (Syn. 14), summing it up in one word: automation. Overall, this sub-topic captures the notion that the 4th Industrial Revolution is about a revolution in technology, from artificial intelligence to "smart" systems, that is radically changing the way we live and work.

*Sub-topic 1.2: Digital and social transformation.*Some participants emphasized the broader social and digital changes brought about by the 4th IR, recognizing the 4th Industrial Revolution as a new digital environment that is transforming society and the economy as a whole. One director described it as "a huge digital transformation that is coming to play a dominant role at all levels of activity" (Syn. 13), suggesting that changes are not limited to industry or technology, but extend to every aspect of life. Another participant noted the positive and negative consequences at the social level (Syn. 4), showing a more holistic view. He perceives the 4th IR not only as a technology, but as a social revolution with a broader impact (e.g. on the way of working, communicating, education).

Sub-topic 1.3: Limited knowledge and/or confusion of the term. A smaller but notable proportion of directors admitted that they did not have a clear knowledge of the term; some had difficulty giving a definition or simply mentioned whatever came to mind. For example, one director frankly stated: "The meaning of the fourth industrial revolution I am not very well informed... I have no knowledge of it" (Syn. 16). Similarly, another participant said, "I generally don't remember what it is, I just associate it in my mind with computers" (Syn. 12), showing a vague or superficial understanding. These cases highlight that the term "4th Industrial Revolution" is not fully understood by all managers. Some people confuse it with general IT concepts or are simply not up to date with the developments and the philosophy behind it.

Table 4: Managers' perceptions of the 4th Industrial Revolution

Code	Interview Excerpt
Technological Revolution (AI & Automation)	"In general, everything that is happening now with artificial intelligence, which is invading everywhere... is very helpful..." (Syn. 2)
Digital transformation	"I perceive it as a huge digital transformation that is coming to play a dominant role at all levels..." (Syn. 13)
Ignorance of the term	"I'm not very informed... I have no knowledge of it" (Syn. 16)

Table 5 *Managers' perceptions of 4th IR technologies in education.* The second main theme concerns the technologies of the 4th Industrial Revolution that managers consider important for education. The responses highlighted a wide range of technologies, from artificial intelligence and robotics, to virtual reality and basic digital tools, as well as the perception that all of these can be used in the educational process.

Sub-topic 2.1: Artificial Intelligence as a leading technology. Artificial Intelligence (AI) was cited by many as the most critical technology of the 4th IR for education. Participants see it as an innovation that can radically change teaching and learning, from smart educational software to personalized learning. One director pointed out that AI is now "in vogue" and at the center: «… lately very fashionable, artificial intelligence" (Syn. 5). Others have described it as a "dominant form" of technology (Syn. 7) that cannot be ignored in education. Overall, there is widespread enthusiasm for AI applications (such as smart learning assistants, AI programs for teaching) believing that they will have the greatest impact on students and schools.

Sub-topic 2.2: Educational robotics and STEM. Many directors mentioned robotics as a key technology with pedagogical value. They find it useful because it brings students into contact with programming, problem-solving, and practical applications of engineering. "I don't know much. I think robotics is very useful..." (Syn. 15) said one principal, showing limited knowledge of other technologies, but certainty that robotics is beneficial in the classroom. Some even included STEM (Science, Technology, Engineering, Math) tools in general, such as microcontrollers, 3D printing, etc., believing that "all these STEM... help students in 21st-century skills" (summary from Syn. 17). This sub-topic underscores the belief that the practical, constructive technologies of the 4th IR enrich the learning environment and encourage creativity.

Sub-topic 2.3: Virtual/Augmented Reality and simulations. Several participants focused on immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR). These technologies are considered important because they make learning more experiential and engaging. As one director said, through VR "you can experience something... learning becomes more experiential, it touches children more" (Syn. 2). With VR, students can "live" educational experiences (e.g. virtual tours, lab experiments) that would otherwise not be possible in the classroom. AR also allows the real-world environment to be augmented with digital information, which also excites those who know it. Some managers have discovered these technologies recently – "I've seen... augmented and virtual reality," commented one (Syn. 18) – and recognized their potential for more vibrant, active learning.

*Sub-topic 2.4: Networking and digital infrastructure.*Some participants emphasized key digital technologies and infrastructures that they consider to be the foundation for educational transformation. They

mentioned distance education and video conferencing, especially after the experience of the pandemic. "The possibility of video conferencing, i.e. computers..." (Syn. 12) was a characteristic phrase, showing that even "traditional" ICT (Information and Communication Technologies) is considered part of the 4th IR in education. Interactive whiteboards, computer networks and digital equipment in general were also mentioned as necessary technologies. Without them, more advanced applications (AI, VR, etc.) cannot be widely exploited. Thus, principals recognize that the digital transformation of schools starts with infrastructure and universal access to key technology.

Sub-topic 2.5: Integrated adoption of all new technologies. It is worth noting that some participants avoided single-handing out specific technologies, emphasizing that all 4th IR technologies can be used in education to some extent. "All of them. … can be used for teaching" (Syn. 3) said one principal, expressing a holistic approach. This attitude suggests an openness to any kind of innovation. From the simplest digital tools to the most advanced applications, anything new can be useful in the classroom if used correctly. This perspective is also linked to the assumption that the school must keep pace with the developments of the 4th IR, without excluding some technology as insignificant.

Table 5: Managers' perceptions of 4th IR technologies in education

Code	Interview Excerpt
Artificial intelligence	«… the latest fashion, artificial intelligence" (Syn. 5)
Educational Robotics (STEM)	«… I think robotics is very useful..." (Syn. 15)
Virtual Reality (VR)	«… you can experience something through Virtual Reality... learning becomes more experiential..." (Syn. 2)
Video Conferencing – Remote	"The possibility of video conferencing, i.e. computers..." (Syn. 12)
All new technologies	"All... can be used for teaching" (Syn. 3)

Table 6 *Managers' perceptions of readiness and adaptation to technological changes.* The third main theme concerns the attitudes of principals towards the changes of the 4th IR and how prepared they feel to manage them in their schools. In general, most of them expressed uncertainty or insufficient preparation, but at the same time they highlighted various adaptation strategies and a positive mood for continuous learning. Here the sub-topics of this third axis are analyzed.

Sub-topic 3.1: Limited preparation – need for continuous learning. Most managers admit that they do not feel adequately prepared for rapid technological change. They often rate their level of readiness low and emphasize that they are still at the beginning of trying to understand and exploit new technologies. "Absolutely not [I'm not prepared], even though I've tried to study... we are, I think, still at the beginning of this technological evolution" (Appendix 7) confessed a director, expressing the feeling that the pace of evolution of the 4th IR is surpassing her. Similarly, many stressed the need for continuous learning and training to cope. "Not prepared, but... continuous training" (Syn. 16) said one participant, summarizing the general feeling that lifelong learning is necessary in order to close the knowledge and skills gap. In this sub-topic, therefore, the moderate self-evaluation of managers is recorded. They consider themselves not fully ready, but they are willing to constantly learn in order to improve.

Sub-topic 3.2: Barriers – lack of training, time and resources. Participants highlighted a number of important barriers that make it difficult for them to prepare. A common obstacle is the lack of available training and time. Many feel that they are not offered enough seminars or training programmes in new technologies, so they have to "spend infinite time" on their own (Syn. 2). In addition, the inadequacy of school infrastructure was highlighted. Many headteachers feel that their school environment is not ready technologically, something that acts as a deterrent. As one director said, "there are a plethora of things that don't fit... Especially when we are talking about schools that do not have infrastructure. The school is not ready, the system itself is not ready" (Syn. 2). This phrase encapsulates the problem. The system does not adequately support digital transformation, leaving teachers alone to struggle with equipment shortages, outdated infrastructure and limited time. This sub-topic illuminates the structural side of the challenge: even if managers are willing to adapt, they are often hindered by external factors.

Sub-topic 3.3: Personal initiatives and self-education. Despite the difficulties, many managers take personal action to fill knowledge gaps. A recurring pattern is self-education. Searching for information online, exchanging good practices with colleagues, or experimenting with new tools in their free time. "Whatever knowledge I have on the subject, I have it after personal occupation, because I sat alone and searched for it..." (Syn. 9) stressed a headmistress, stressing that formal training was inadequate and she was forced to learn on her own. Others reported attending seminars on their own initiative: "I have already attended several seminars... and I believe that I can..." (Syn. 18), noted a director who invested in training on artificial intelligence and VR. More generally, this sub-topic highlights a culture of self-improvement. Directors who are genuinely interested do not passively wait for state concern but mobilize themselves to keep up with the 4th IR.

Sub-topic 3.4: Attitudes – willingness to adapt versus reluctance. The attitudes of the participants towards technological change combine willingness and enthusiasm with a certain reticence due to difficulties. Many showed a positive mood, even if they do not feel fully capable, at least they have the will to try. "I feel prepared, because... I have the will. I consider it necessary to have the will..." (Syn. 3) mentioned one participant, underlining that mental readiness and a positive attitude are the first step. Correspondingly, a more experienced manager who no longer feels very familiar with new trends, said, "No, by no means [I'm not fully prepared]. … even now I have all the mood" (Syn. 13), adding that although he is older, he still has the appetite to learn. These positions show that acceptance of change is present. Most people want to adapt and are not afraid of technology as something negative. At the same time, however, there is also a reluctance – not resistance to change, but concern about whether they will be able to keep up in practice. This concern is linked to the aforementioned obstacles (lack of time, knowledge, resources). To sum up, attitudes range from slight concern to focused enthusiasm: no one denies the value of digital transformation, but everyone realizes that it takes effort and support to achieve it.

Table 6: Managers' perceptions of readiness and adaptation to technological changes

Code	Interview Excerpt
Insufficient preparedness	"Absolutely not... We are, I think, still at the beginning of this development" (Syn. 7)
Lack of support (infrastructure/time)	«… They don't fit. And especially when we talk about schools that do not have infrastructure. The school is not ready..." (Syn. 2)
Self-education and personal effort	"Whatever knowledge I have... I have it after a personal occupation, because I sat alone and searched for it..." (Syn. 9)
Will and positive attitude	"No, not at all [prepared]. … even now I am fully inclined [to learn]" (Syn. 13)

Chart 1. *Managers' knowledge of the 4th Industrial Revolution.* In summary, the thematic analysis highlighted a complex picture of managers' knowledge and attitudes towards the 4th Industrial Revolution. On the one hand, they recognize the transformative character of the 4th IR. They understand both technological innovations (artificial intelligence, robotics, VR, etc.) as well as the broader changes in society. In addition, they appreciate the educational value of many of these technologies and are willing to integrate them into schools, considering them the key to a modern, attractive learning environment. On the other hand, they feel the challenge of adaptation. Most of them feel inadequately prepared and point out the obstacles that need to be overcome (need for training, improvement of infrastructure, change of mentality). Nevertheless, their overall attitude is positive and energetic. They do not face changes with fear. On the contrary, they demonstrate a will and initiative to learn. Broadly speaking, the findings outline a group of educational leaders who are realizing the importance of the 4th Industrial Revolution and striving to bridge the gap between the present and the digital future.

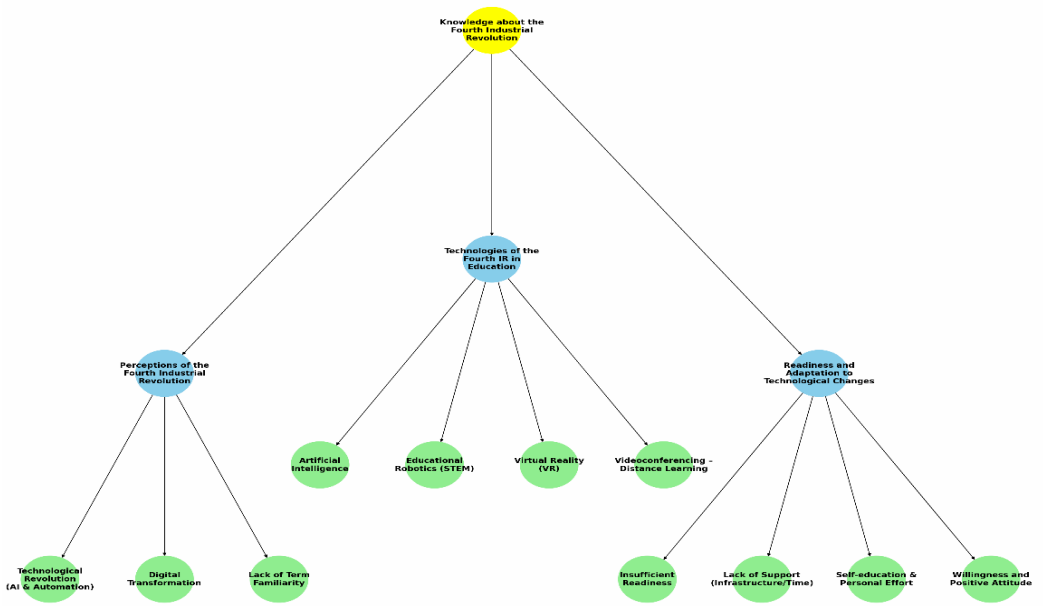

Chart 1. Managers' knowledge of the 4th Industrial Revolution

IV. Discussion

The findings of quantitative research and qualitative research are compared and correlated with leadership knowledge of the 4th Industrial Revolution. The analysis is organized into three thematic units: a) Knowledge and understanding of the 4th Industrial Revolution, b) Leadership preparedness and change management and c) Attitudes and perceptions towards technological change and its challenges.

a) *Knowledge and understanding of the 4th Industrial Revolution.* The quantitative findings suggest that principals generally have sufficient knowledge of the technological developments introduced by the 4th Industrial Revolution. According to 76% of the 1359 teachers surveyed, school leaders understand how key technologies such as Artificial Intelligence, the Internet of Things (IoT) and robotics affect the functioning of the school. This finding is consistent with previous studies where principals state that they feel qualified for the requirements of IR4 [3]. However, some areas of knowledge with lower levels of familiarity are also identified: only 62% of teachers agree that school management understands the role of more advanced technologies, such as blockchain and big data analysis. This trend is not surprising, as the literature states that concepts such as blockchain and Big Data are often considered abstract or less understood at the leadership level[37]. On the contrary, there is a particularly high agreement (over 80%) on issues such as the use of new technologies to improve school administration (81.5%) and – even more strongly – on the importance of cybersecurity (85.2%). It is characteristic that 85% of teachers recognize that headteachers are aware of the importance of data protection and digital security in school. Overall, the quantitative responses of teachers paint a positive knowledge picture, with the majority believing that managers are adequately proficient in the basic technological concepts of the 4th IR.

Data from managers' interviews offer a more detailed and qualitative dimension of this picture. Many managers perceive the 4th Industrial Revolution primarily as a technological development, focusing on key innovations such as artificial intelligence and automation. Characteristically, several people specifically referred to the development of AI and robotic systems as the main features of the new era, which also reflects the international literature on the decisive role of these technologies in the 4th IR[21, 30]. However, some directors have extended the concept beyond the purely technological field, underlining that this is a broader digital transformation with significant social and economic dimensions. This perspective aligns with the position of [40], who emphasizes that the 4th Industrial Revolution is not limited to a set of new technologies, but constitutes a profound global change that is redefining society and the economy. It is also noteworthy that in individual cases the directors themselves have admitted confusion or incomplete knowledge about the term "4th Industrial Revolution". One interviewee said that he is not at all informed about what the term means. Similar findings appear in the international literature: field studies have shown that some educators lack specialized knowledge of these technologies and prioritise traditional administrative responsibilities over technical guidance[16]. Therefore, while the overall picture is that most leaders have understood the basic principles of the 4th IR, the level of knowledge is not uniform everywhere: a small percentage of managers seem to have difficulty defining the concept clearly or feel uncertain about its content.

With regard to the technologies of the 4th IR that managers consider to be more important for education, it appears that a particularly wide range is mentioned. Artificial Intelligence (AI) emerged as the most defining technology, with many participants describing it as an innovation that can radically transform teaching and learning. At the same time, the role of educational robotics and STEM tools was highlighted, which, according to the principals, bring students closer to programming, problem-solving and other fundamental skills of the 21st century. In addition, several managers expressed enthusiasm for technologies such as Virtual Reality (VR) and Augmented Reality (AR), believing that they offer more experiential and engaging learning experiences. This belief reflects the international trend of utilizing these technologies in education, as VR/AR has been found to improve the understanding of complex concepts and the active participation of students, creating immersive learning experiences[8, 39]. Along with the cutting edge of technology, the value of basic digital infrastructures was also highlighted by the managers. References were made to the necessity of distance education, video conferencing systems, interactive whiteboards and general digital equipment, as fundamental prerequisites for the utilization of the most advanced applications. Some directors took a holistic approach, stating that all the new technologies of the 4th IR can have a place, to some extent, in the learning process. This universal openness to innovation testifies to a culture of receptivity. From the simplest digital tools to the most sophisticated applications, they believe that anything new can be useful if used correctly in school.

The findings of the quantitative and qualitative approaches ultimately converge on a single overview of the specific topic. Teachers, through their responses, recognize in their principals a significant level of knowledge and understanding about the 4th Industrial Revolution, and this assessment is confirmed by the descriptions of the principals themselves in the interviews. In other words, what teachers "see" in the numbers –

the high positive responses – is reflected in what the principals say, who in their own words describe the technologies and changes of the 4th IR, often with obvious enthusiasm for AI, robotics, VR and other innovations. This agreement between the two data sources suggests a convergence of perceptions, a finding that agrees with studies where school leaders demonstrate a positive attitude towards technological innovation[16]. At the same time, the qualitative phase adds depth to the understanding, revealing important details that were not highlighted by the quantitative data. For example, while about 75–80% of teachers say that managers have sufficient knowledge, interviews have shown that there is a small portion of managers who do not feel adequately informed or confident about the term "4th Industrial Revolution". This finding does not negate the overall positive picture, but clarifies it. It highlights that knowledge is not completely uniform among all executives, and that there is always room for further information and specialization in certain fields. In addition, teachers appeared more restrained when it comes to very emerging technologies (e.g. blockchain, Big Data), which is also reflected in qualitative data. Managers rarely spontaneously mentioned these technologies, suggesting that they are not an immediate priority in their thinking. To sum up, the first thematic section records a broad agreement. Principals have a positive attitude and an adequate knowledge base about the 4th Industrial Revolution according to the teachers, and the leaders themselves confirm this picture through their words – adding of course their own pointing out that there are still areas in which they would like more information. The literature confirms that educational leadership is on this positive trajectory, but at the same time it needs continuous support and training to feel fully prepared in the new digital environment[37].

b) *Leadership readiness and change management.* When it comes to the readiness of school leadership to manage the changes brought about by the 4th Industrial Revolution, teachers' views paint a cautiously optimistic picture. About two-thirds (68%) of teachers surveyed believe that their school principal is to some extent prepared to cope with the rapid technological changes of the new era. Almost all teachers recognize that effective leadership in such a dynamic environment requires continuous training and adaptation. A very high percentage, almost 90%, agree that managers understand the value of lifelong learning and vocational training in order to keep up with developments. Also, the majority agree that headteachers actively support the introduction of new digital tools and teaching methods in the school, in response to the challenges of the 4th IR. In other words, from the point of view of teachers, school leadership seems to have a positive predisposition in favor of change and a basic readiness, emphasizing the need for continuous development and innovation. This perspective is in line with the modern approach of Education 4.0, whereby effective educational leaders must encourage innovation and promote the adoption of new technologies, while remaining committed to continuous learning[5, 6]. Research highlights that adaptive and transformational leadership, i.e. leadership that is flexible, innovative and strategically oriented in the use of technology, is a prerequisite for effectively guiding schools in the digital age[6]. Moreover, the emphasis that teachers place on the value of lifelong learning reflects a more general assumption in the literature that continuous professional development is critical for 21st-century educational leadership[17, 45]. Leadership that is constantly learning and adapting – both in terms of knowledge and skills – is able to inspire and guide a culture of continuous improvement in the school[19].

The perceptions of the directors themselves present a complementary but somewhat more moderate perspective. Most managers admit in interviews that they do not feel completely ready for the rapid pace of technological changes that 4th IR brings. Although teachers rated school leadership as relatively prepared, the leaders themselves appear to be more rigorous in their self-evaluation. They emphasize that they are still at the beginning of the adjustment process and that the pace of developments is often beyond them. This finding helps in the interpretation of quantitative data as well. About a third of teachers said they had a "neutral" stance on leadership readiness, indicating an uncertainty. The statements of the directors explain that this uncertainty stems from their own awareness that they have not yet reached the desired level of readiness. In any case, managers also emphatically recognize the need for continuous learning. In fact, many underlined that the only realistic solution to cope with the challenges is continuous training and information on new developments. This attitude is in full agreement with teachers' view that leadership values and promotes lifelong learning, while reflecting the general assumption in the international literature that educational leaders themselves need to remain students throughout their careers[33, 45]. Indeed, continuous professional leadership development has been shown to reduce anxiety and uncertainty in the face of technological change and enhance a sense of competence to lead that change[33].

In addition, the headteachers highlighted a number of practical factors that make it difficult for them to be fully prepared, thus complementing the picture of the quantitative findings. In particular, they spoke of shortcomings in training, limited available time and insufficient digital infrastructure in schools. These barriers were not reflected in the questionnaire, but they largely explain why adapting to the 4th IR is not an easy task. Reporting of these challenges by managers is consistent with known barriers recorded in the international literature regarding the integration of technology in education. For example, a lack of adequate training and time, as well as inadequate infrastructure, have been documented as the main causes of slowing down the digital transformation of schools[13]. As research has shown, when a school faces serious gaps in technological resources

or its staff is afraid/resistant to change, progress in the uptake of ICT is slow. On the contrary, when external challenges are reduced – i.e. when infrastructure is in place, support is available and fear is addressed through appropriate training – then the implementation of digital practices is significantly enhanced[27, 48]. In this context, the directors involved in this study seem to be experiencing precisely these challenges: they know what needs to be done; But they recognize that limited time, lack of organized training and lacking infrastructure are a brake on their efforts to stay fully informed.

It is worth noting, however, that despite the objective difficulties, many directors described how they undertake personal initiatives to fill their gaps. Many reported that they are self-educated, seeking information on new trends on their own (e.g. by studying articles, attending online courses or relevant workshops) and exchanging good practices with colleagues. Others noted that, on their own initiative, they attend additional seminars and training programs on new technologies, in addition to the (few) official training actions offered. This active and self-directed attitude on the part of leadership complements the quantitative findings, showing that educational leadership not only recognizes the need for change, but also tries to respond to it in practice. The image of the self-educating and collaborative manager reflects what the literature suggests: effective digital transformation leaders build learning networks and communities of practice, leveraging the support of external stakeholders and colleagues to enhance their knowledge and skills[45]. In this way, they manage to mitigate some of the obstacles (e.g. the formal training gap) and maintain a degree of preparedness, even if the system does not provide them with all the necessary skills. Overall, the triangular view in the second thematic also reflects a convergence but also some nuances. Teachers see a leadership that is willing to change and aware of the need for continuous development, while principals agree on this need but emphasize the practical difficulties and shortcomings. Both sides, however, converge on the recognition that continuous learning, flexibility, and the search for solutions are central to successful leadership in the 4th Industrial Revolution.

c) *Attitudes and perceptions towards technological change and its challenges.* The attitudes of teachers and principals towards technological change present important points of convergence. Teachers, to a very large extent, perceive that school leadership is positively dealing with the new technologies and changes that the 4th IR brings to the school. Indicatively, more than 80% of the participating teachers agree that the management recognizes the value of digital tools for improving school operation and teaching. In other words, according to the teachers, the principals demonstrate a willingness to accept innovation and a willingness to exploit the potential of technology for the benefit of the school. This image suggests a leadership that embraces innovation, which has also been highlighted in the literature: when management communicates a clear vision of the benefits of innovation and shows enthusiasm for it, teachers are more easily persuaded to try something new[19, 41]. In addition, research findings confirm that a supportive and encouraging attitude of management increases teachers' internal motivation to engage in innovations and innovations. facilitates the development of positive attitudes towards Information and Communication Technologies (ICT)[2]. Therefore, the fact that teachers perceive a positive attitude from their headteachers is in line with the theoretical framework linking encouragement from leadership to the acceptance of technological innovations in the school environment.

The directors themselves, through interviews, generally confirm this positive attitude, but add some important nuances. None of the participating directors expressed negativity towards technological change. On the contrary, most said they were enthusiastic about the opportunities offered by the new digital environment in both learning and school administration. Many noted that they are willing to adapt to developments and are not afraid of technology as something threatening or undesirable. This universal acceptance of change is perfectly in line with the picture that teachers have described of the attitude of leadership. It is clear that school leaders perceive technological progress as something positive, which can improve the functioning of the school and enhance learning. This leadership's commitment to new technologies reflects the ideal type of leader of the digital age described in the literature. A leader with vision and a positive attitude, who creates a culture of continuous improvement and encourages teachers and students to embrace change[5, 6].

Nevertheless, the directors expressed both a restrained concern and a reservation amid the general positive climate. In particular, although they are not negative towards the changes, they are concerned about whether they will be able to practically keep up with such a rapid pace of development. This element is a differentiation highlighted by qualitative research. Teachers, judging "from the outside", mainly see the positive mood of the management, while the principals themselves, experiencing the change "from the inside", also feel the stress of adaptation. This concern of leaders is directly linked to the above-mentioned obstacles (lack of time, lack of training, inadequacy of infrastructure). In other words, it is not a question of fear of technology itself, but of a realistic awareness of the challenges that accompany its implementation. In the international literature, it is often reported that even technology-positive educational leaders experience stress when they do not have the necessary support or time to implement the changes[4, 29]. The directors of our study essentially repeat this pattern: they embrace technology, but at the same time they honestly recognize the practical hurdles that need to be overcome to make full use of it. This sober concern should not be seen as resistance or denial, but rather as a sign of a responsible attitude. Managers understand the potential of the 4th IR, but they are well

aware that turning these capabilities into practice requires time, training and support – factors that, as they point out, are not always guaranteed.

In any case, the findings from both sides – teachers and principals – coincide with the fact that school leadership recognizes the value of digital transformation and demonstrates a positive willingness to evolve with it. The image of an educational leadership that "embraces" the 4th Industrial Revolution and its changes is formed, being aware of both the possibilities and the challenges it entails. Managers already have the foundations – knowledge, willingness, adaptability – and their attitude towards innovation is clearly in favour of innovation. According to the existing literature, more and more educational leaders worldwide are adopting such an attitude, recognizing that technological change is inevitable and valuable, but also that it requires strategic response and preparation[14, 44]. The qualitative dimension of our survey underlined that, despite the positive orientation, leaders feel the need for more support in order to be able to keep up with the pace of change. This finding is consistent with international experience. Education policies are now called upon to focus on providing the appropriate resources, training opportunities and infrastructure so that school leaders can bridge the gap between the present and the digital future of education[15, 32]. To sum up, school leadership in the era of the 4th Industrial Revolution appears ready to lead the changes, maintaining an optimistic but at the same time realistic attitude. The knowledge is there and the mood is positive; With continuous learning, appropriate training and the necessary support from the wider education system, principals can further enhance their readiness and effectively lead their schools into the new digital era.

V. Conclusion

The present study has shown that school principals have a generally positive attitude and basic knowledge adequacy in relation to the 4th Industrial Revolution. Technologies such as artificial intelligence, robotics, and digital tools are recognized as critical elements of the modern school. At the same time, there was a strong acceptance of the digital transformation, as well as a realistic awareness of the challenges it entails. Managers show a willingness to adapt and take initiatives, while recognizing the need for continuous training and support. For their part, teachers see leaders as willing allies of change, although they identify differences in readiness and knowledge of specialized technologies. Overall, the picture emerges of a school leadership that is on a positive path of adaptation, but needs reinforcement, especially in terms of infrastructure, time and targeted training, in order to confidently lead the school of the future.

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