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Identifying the Dimensions and Components of Internet of Things (IoT) Development in Schools Based on Futurology

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A B S T R A C T

Purpose: Futurology plays a significant role in advancing organizational goals and mitigating organizational problems and challenges. Therefore, the aim of this study was to identify the dimensions and components of Internet of Things development in schools based on future studies.

Methodology: In a descriptive qualitative study, 19 academic and organizational experts from the educational sector of Tehran were interviewed in the academic year 2020-2021 using a semi-structured method. In this study, the sample size was determined according to the principle of theoretical saturation and was selected through purposive sampling. The research tool was a semi-structured interview, whose validity was confirmed through triangulation and whose reliability was calculated at 0.88 using the agreement coefficient between two coders. The data of this study were analyzed using thematic analysis in MAXQDA software, version 2020.

Findings: The analysis indicated that the development of the Internet of Things in schools based on future studies encompasses 26 components across 7 dimensions. These dimensions include the elimination of time constraints (with 3 components), elimination of spatial constraints (with 4 components), reduction of infrastructure costs (with 4 components), knowledge management (with 3 components), professional competence (with 3 components), information technology (with 3 components), and effectiveness of the educational system (with 6 components). Ultimately, a thematic network for the development of the Internet of Things in schools based on future studies was established.

Conclusion: The model of dimensions and components designed in this study can assist specialists and educational system officials in improving the development of the Internet of Things in schools.

Keywords: *Internet of Things, schools, futures research, knowledge management, information technology, educational system effectiveness.*

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1. Introduction

Technologies are changing and evolving at a very rapid and remarkable pace, and alongside the creation of new technologies, previous technologies also grow and develop (Cranmer et al., 2022). Nowadays, the internet has become a vital tool for many people, requiring users to provide necessary information and additionally, due to its multimedia features, enables users to use it easily (Askari et al., 2021; Atlam et al., 2020). The rapid and extensive advancement of science and technology has led to major changes and transformations in societies, and the emergence of new technologies that open new paths for solving problems has become a reality in today's societies. Consequently, governments are inclined to benefit from these technologies through appropriate policy-making (Li et al., 2020). The main goal of smart environments is to facilitate everyday life, and people, when driving, want to be able to obtain the latest information about road conditions and traffic density. Moreover, they can change radio networks to other networks and, with the help of built-in sensors and smart devices that combine all these elements, individuals can check the weather on the internet just by using their voice (Wicaksono et al., 2022). The internet has evolved with the connectivity and connections it has created between people and videos, photos, texts, and physical objects, and through the use of sensors, physical objects can communicate with each other and even issue commands to carry out a physical operation (Goyal et al., 2021).

The Internet of Things (IoT) is a network of physical objects that include embedded technologies that use these sensors to communicate and sense their internal state or external environment (Ahmad et al., 2022). This structure is a network that connects information according to a specific protocol using technologies like radio frequency identification, wireless communication technologies, infrared sensors, global positioning systems, and laser printers among other sensor tools (Cheng et al., 2021). IoT comprises hardware (the objects themselves), embedded software, communication services, and object-related information services (Atlam et al., 2020). This structure processes, transfers, manages, tracks, and produces vast amounts of data. Such data have the potential to automate decision-making and improve operational performance and service quality (Wang et al., 2022). IoT elevates traditional thinking and enables the connection of many objects such as cars, household appliances, and other electronic equipment within a network, providing a smarter life for humans (Rao & Elias-Medina, 2024). In recent decades, IoT has influenced the world and encouraged organizations to use and invest in this area by offering innovative solutions in various sectors. The idea of IoT was first proposed by Ashton in 1999, stating that the internet had connected people with each other, but IoT could enable the connection of inanimate objects with each other (Zargar, 2019). Since 2005, the development of smart objects with sensitive and communicative capabilities has experienced rapid growth, and such smart objects with network capabilities have countless applications in areas such as environmental monitoring, smart healthcare, logistics transport, social networks, and smart buildings (Gharakhani & Pourhashemi, 2021). The momentum of companies and organizations to operationalize IoT projects indicates the promising future of this technology, and this structure is an emerging paradigm for connecting physical devices with the aim of seamlessly integrating the physical world into internet-equipped systems, leading to increased efficiency and broader applications in various fields (Palmaccio et al., 2021).

In the emerging world of education and learning, new technologies including IoT are extensively used. IoT is one of the technologies that can play an important and effective role in education and learning, transforming and revolutionizing educational methods (Terzieva et al., 2022). IoT in education, which sets internet connections between physical objects, sensors, and controllers, has drastically changed educational institutions and the concept of education. Nowadays, IoT in education has shifted from a knowledge transmission model to an autonomous collaborative model with technology's influence in educational institutions, compelling many institutions to teach and learn (Mohammadian et al., 2022). In the traditional teaching method, the teacher was the focus of education, but IoT has eliminated this centrality, and students, along with the teacher, are engaged in teaching, education, and learning. In IoT-based education, there are no more boundaries for the classroom, and all schools, teachers, and students related to the subject are connected and share microdata with each other. Thus, this technology, instead of using outdated textbooks, uses real-time information from multiple sources (Gul et al., 2017).

One of the research approaches in any field is futures research, which investigates three futures: possible futures that are feasible, probable futures that are more likely than others, and desirable futures that align with the values and ideals of employers and futurists (Di Zio et al., 2023). The term futures research was first coined by Flechtheim in 1966,

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but understanding the future in the late decades of the twentieth century was established as the science of futures studies or futures research. Futures research involves a collection of efforts that use the analysis of resources, patterns, and factors of change or stability to envision potential futures and plan for them. In other words, futures research means predicting tomorrow's reality from changes or non-changes (Lashkari et al., 2021). Futurists are engaged in systematic and continuous examination of current events and trends to sketch future scenes. Most futures research methods are based on polling experts, specialists, and experts and reducing divergence among their opinions, which itself leads to a relative unity among their views (Rezapour et al., 2021). Indeed, futures research is both the science and art of discovering and shaping the desirable world of tomorrow, and futurists use today's changes and transformations to recognize and predict the future (Kuusi et al., 2016). Therefore, futures research is an independent and structured scientific discipline that studies the future and provides images of the future to individuals so they can make more efficient decisions in the present (Fergnani, 2019). For example, Khedmatgozar (2015) concluded in his research on the role of IoT in knowledge management systems that the use of IoT in two areas, data collection and entry and exit management, encompassing six specific areas, aids in improving employee performance; thus, IoT can be reliably used in the production of data from knowledge processes, especially in discovering knowledge in physical and digital environments (Khedmatgozar, 2015).

In less than a decade since the concept of the Internet of Things (IoT) was introduced, by the year 2008, the number of interconnected objects exceeded the global population. It is projected that by 2020, their number would reach at least 50 billion and possibly up to 100 billion connected objects. The development of IoT technology has garnered the attention of policymakers in the field of advanced technology, and efforts have been made to devise strategies and roadmaps for it (Mousakhani et al., 2022). Internet protocol-based services enable users to access information on their IoT objects anytime and anywhere, and if necessary, integrate these services (Askari et al., 2021). Given that research approaches utilize future studies and futurists explore possible, probable, and desirable futures, examining IoT based on future studies can significantly assist experts and planners in understanding the current state and planning for its improvement. Consequently, it seems that future research plays an important and effective role in advancing organizational goals and mitigating organizational problems and challenges. Therefore, the aim of this study was to identify the dimensions and components of IoT development in schools based on future studies.

2. Methods and Materials

2.1. Study Design and Participants

In a descriptive qualitative study, 19 academic and organizational experts from the education sector of Tehran were interviewed during the academic year 2020-2021 using a semi-structured approach. In this study, the sample size was determined based on the principle of theoretical saturation, and these individuals were selected through purposive sampling. Therefore, the study population included all academic and organizational experts from the Tehran education sector, of whom 19 were selected based on theoretical saturation using purposive sampling. Theoretical saturation implies that before beginning the research, there is no specific rule for sampling, and sampling and research on individuals continue until new samples cannot add findings to those of previous researchers, meaning the research has reached saturation. Furthermore, in purposive sampling, academic and organizational experts from the Tehran education sector were selected based on criteria such as having at least a Master's degree, more than one year of job experience, consent to participate in the research, and agreement to record the interview. It should be noted that in this study, 7 academic experts and 12 organizational experts participated; academic experts were chosen based on criteria such as having at least three years of teaching experience, education related to future studies, holding a PhD in educational management, curriculum planning, educational research, and having sufficient expertise and experience in future studies including articles, books, research projects, etc. Similarly, organizational experts were selected based on criteria such as proficiency in the Internet of Things and future studies, more than five years of experience in education, future studies, management, policy-making, operational history, etc., sufficient expertise and experience in future studies such as articles, books, research projects, etc., and holding at least a Master's degree in educational sciences.

For conducting this study, questions for interviewing the academic and organizational experts from the Tehran education sector were initially designed, and then efforts were made to identify experts, for which purposive sampling was used based on the criteria and standards described above. After identifying the samples and before conducting

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the interviews, the importance and necessity of the research were explained to the experts, and while describing the conditions for participating in the research (including recording the interviews), the researcher committed to ethical considerations such as explaining the importance and necessity of the research, keeping participants' information confidential, providing research results to participants upon request, voluntary and optional participation in the research, obtaining permission to record interviews, not manipulating data, and maintaining trust in the use of sources. Interviews were conducted at a designated time and place individually, in addition to recording and noting important content and concepts, interviews were recorded to review interviews and record and note forgotten concepts and content with the help of a research colleague.

2.2. Measures

2.2.1. Semi-Structured Interview

The research tool used was a semi-structured interview. In this study, after reviewing documents related to the Internet of Things and gaining sufficient information about future studies with the help of academic experts, several questions were designed for interviewing the academic and organizational experts from the Tehran education sector. These questions included five main questions and several sub-questions; all experts were asked about the main questions, but sub-questions were only asked of experts who became unclear in their responses to the main questions or who deviated from the framework of the main question response. Interviews were conducted individually and lasted about 35 to 50 minutes with each of the academic and organizational experts from the Tehran education sector. During the interviews, concepts and content were recorded, noted, and after each question, recorded and noted items were read to the experts and corrected if necessary. It is worth noting that the validity of the interviews was confirmed through triangulation, and their reliability was calculated with an agreement coefficient between two coders at 0.88.

2.3. Data Analysis

After each interview, coding and thematic analysis were conducted, and this process continued until new samples could not add new findings to previous findings. Finally, the data of this study were analyzed using thematic analysis in MAXQDA software, version 2020.

3. Findings and Results

This study reached theoretical saturation after interviewing 19 academic and organizational experts from the Tehran education sector. Most of the academic and organizational experts from the Tehran education sector included organizational experts at 63.16%, male at 52.63%, aged 51 to 55 years at 31.58%, and with a job tenure of 11 to 20 years at 42.10%. The thematic analysis of the development of the Internet of Things in schools based on future studies according to academic and organizational experts from the Tehran education sector is presented in Table 1.

Table 1

Thematic Analysis of the Development of the Internet of Things in Schools Based on Future Studies According to Academic and Organizational Experts from the Tehran Education Sector

Dimension	Component
Elimination of Time Limits	Connectivity at any time
	Use without restrictions
	Offline utilization
Elimination of Space Limits	Use in any location
	Use at school and home
	Utilization without specific equipment
	Usability with computers
Reduction of Infrastructure Costs	Sharing of teachings
	Direct transfer of teaching
	Elimination of special infrastructure facilities
	Direct connection to the system
Knowledge Management	Creation of knowledge

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	Transfer of knowledge
	Distribution of knowledge
Professional Competence	Cognitive competence
	Knowledge competence
	Skill competence
Information Technology	Automation of information flow
	Easy access to information
	Organizational transformation
Educational System Effectiveness	Efficient education
	Behavioral patterns timely
	Talent-based as per future needs
	Alignment of school inputs with future expectations
	Satisfactory educational process
	Provision of satisfactory educational services as per future needs

According to the results of Table 1, the development of the Internet of Things in schools based on future studies according to academic and organizational experts from the Tehran education sector had 26 components in 7 dimensions including elimination of time limits, elimination of space limits, reduction of infrastructure costs, knowledge management, professional competence, information technology, and educational system effectiveness. Therefore, the results of the dimensions and number of components of the development of the Internet of Things in schools based on future studies according to academic and organizational experts from the Tehran education sector are presented in Table 2.

Table 2

Results of Dimensions and Number of Components of the Development of the Internet of Things in Schools Based on Future Studies According to Academic and Organizational Experts from the Tehran Education Sector

Dimension	Number of Components	Total Components
Elimination of Time Limits	3 components	26 components
Elimination of Space Limits	4 components	
Reduction of Infrastructure Costs	4 components	
Knowledge Management	3 components	
Professional Competence	3 components	
Information Technology	3 components	
Educational System Effectiveness	6 components	

According to the results of Table 2, the development of the Internet of Things in schools based on future studies according to academic and organizational experts from the Tehran education sector had 26 components in 7 dimensions; specifically, the dimensions of elimination of time limits had 3 components, elimination of space limits had 4 components, reduction of infrastructure costs had 4 components, knowledge management had 3 components, professional competence had 3 components, information technology had 3 components, and educational system effectiveness had 6 components. As a result, the model of the Internet of Things in schools based on future studies according to academic and organizational experts from the Tehran education sector is presented in Figure 1.

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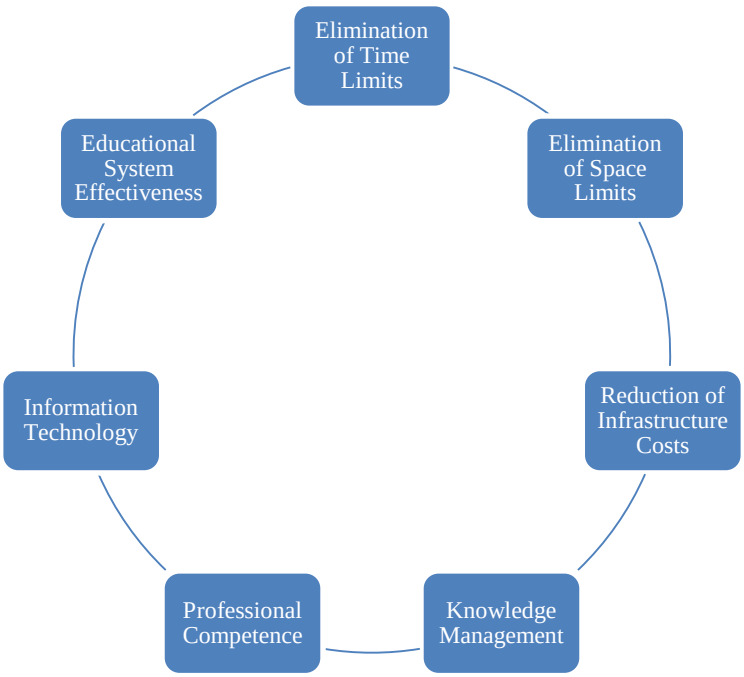
Figure 1

Final Paradigm Model



4. Discussion and Conclusion

The Internet of Things (IoT) is a phenomenon that has recently captured global attention, with major organizations incorporating IoT into their operations. Today, its use in all organizational sectors has become essential and affects all aspects of individuals' activities. One sector where IoT can have a significant impact is the education and learning system or educational administration. With the implementation of IoT-based education, students can better explore and understand their environment through embedded sensors. Moreover, they can access educational content and other information anytime and anywhere. Thus, the purpose of this study was to identify the dimensions and components of IoT development in schools based on future studies.

The examinations and analyses of the current research indicate that the development of IoT in schools based on future studies had 26 components across seven dimensions. These dimensions included the elimination of time constraints (with 3 components), elimination of location constraints (with 4 components), reduction of infrastructure costs (with 4 components), knowledge management (with 3 components), professional competence (with 3 components), information technology (with 3 components), and effectiveness of the educational system (with 6 components). Although no research was found specifically on the development of IoT in schools based on future studies and most prior research in the country has focused on aspects of smartifying schools and the problems and challenges of smartifying schools and prioritizing each of these, the findings of the current research align with the prior studies (Ahmad et al., 2022; Gul et al., 2017; Mohammadi & Hematian, 2022; Mohammadian et al., 2022; Rao & Elias-Medina, 2024; Terzieva et al., 2022; Wang et al., 2022).

This study confidently described findings across seven dimensions including time constraints, elimination of location constraints, reduction of infrastructure costs, knowledge management, professional competence, information technology, and effectiveness of the educational system, asserting that IoT in education, which establishes internet connections among physical objects, sensors, and controllers, has drastically changed educational institutions and the concept of education. Nowadays, IoT in education has shifted from a model of mere knowledge transmission to one of active collaboration. The technology of IoT in modern learning environments involves accessing big data from objects providing services to teachers, learners, and even content developers, thereby enhancing learning conditions. Thus, proper integration of IoT technology in classrooms, along with behavioral and social analysis, creates a smart learning environment where everyone actively listens and

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many behaviors and activities are influenced. Internet technology enables educational systems and institutions to easily receive and collect vast amounts of data from sensors and various devices, perform effective actions and analyses on them, and ultimately, take actions based on those analyses. Therefore, IoT improves the quality of communications in education and learning, allowing learners to access learning materials and other educational resources from anywhere at any time, and instructors can utilize smart devices for teaching and learning both inside and outside the classroom.

Undoubtedly, utilizing IoT technology can address issues such as the confinement of education to a specific time and place, wastage of class time due to high student density, outdated teaching methods, the non-smart nature and high maintenance costs of educational centers, inadequate supervision over students' health and hygiene, unsuitable educational spaces for physically disabled individuals, and the non-smart transport system. Therefore, managers and officials of the educational system in this area can work on the production, reproduction, dissemination, control, supervision, management, and access to knowledge and information. Consequently, the interaction of IoT and the services it provides plays a significant and effective role in control, supervision, access development, smartification, security, education, innovation, and motivation. Quick and appropriate feedback in the teaching and learning process enables the interaction and sharing of data generated from connected objects in the classroom with other educational centers, automates many time-consuming classroom activities, facilitates the sending of educational materials to absentees, and many other applications, all leading to the improvement of learning processes and enhancing the productivity of educational and learning environments. The application of IoT in educational environments is realized not just as a tool for facilitating daily activities but also leads to a sufficient understanding of the functionality and effectiveness of this technology in the learning environment. Consequently, IoT in education, by providing effective and virtual teachings, ensures that teaching hours are more flexible. In such conditions, there is no need for students and teachers to be present at a specific time and place, and the choice of a comfortable space for education is at their disposal, which increases the effectiveness of education and reduces the wastage of educational time.

The limitations of this study included two categories: limitations beyond the researchers' control and limitations within the researchers' control. Inherent limitations exist in any research, but the controlled limitations are those chosen by researchers, such as the qualitative and cross-sectional nature of the research, the use of purposive non-random sampling, etc. Therefore, further research on IoT in schools based on different approaches and prioritizing the identified dimensions and components is recommended. It is also suggested that the effect of each identified dimension and component in this study be examined and evaluated so that more effective strategies can be used to improve the current situation. According to the results of the current research and based on the model of dimensions and components designed in this study, experts and officials of the educational system can use them to improve the development of IoT in schools. Based on the discussions presented, this research is of high importance and necessity, so it is recommended that this research also be examined in other communities.

Authors' Contributions

The first author was responsible for conducting the interview and collecting data, and the other authors were responsible for analyzing the data and writing the article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance

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of the research before the start of the interview and participated in the research with informed consent.

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