

# Education In The Era Of Smart Cities: Transformation And Opportunities

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**Abstract.** The concept of the smart cities is closely related to the opportunities of smart education that reflects how advanced technology enables learners to acquire knowledge and skills more effectively, efficiently, and conveniently. The role of smart education is to support learners in the 21st century to meet and successfully cope with the challenges of a digitalized society, including developing problem-solving skills. The aim of the paper is to examine the role of the education in modern smart cities, from the quadruple helix model perspective. Smart education has become an important strategy for building a smart society, as an essential part of the model, including collaborative innovation and interaction among government, academia, business and society. By the use of technologies and innovation, the modern educational institutions could promote not only student satisfaction with the learning process, but also support the development of sustainable smart and knowledge-based cities.

**Keywords:** education, innovation, smart city, technologies

## I. INTRODUCTION

The concept of smart cities is associated with the use of information and communication technologies (ICT) in the infrastructures of cities to improve living conditions, promote economic development and reduce the harmful impact of climate change and the environment. The main aspects in the construction of smart cities are the achievement of intelligence in city management, infrastructure, health care, transport, education, energy use and the provision of utility services [1]. Smart cities aim to promote sustainable economic growth, improve citizens' quality of life and optimize infrastructure, through the use of data and smart technologies. Global trends in the development of smart cities are aimed not only at the use of technologies in the form of various sensors, hardware and software, smart meters, access control, video surveillance, power and lighting management, sensors, firmware and others that provide information and real-time

data [2], but also integrating the latest technological advances, such as the Internet of Things (IoT), big data, machine learning, fifth generation (5G) networks, various robotic and automated systems, electric vehicles and so called [3] [4]. The purpose of the article is to highlight the importance of smart cities in the field of education and to analyse the possibilities for introducing innovations and technologies in the education.

Digital technologies have enormous potential to help increase the quality, equity and effectiveness of higher education. Realizing the full potential of digitization requires a rethinking of the policy framework, including ways of funding, additional training and quality assurance. An adequate strategic framework of digitization, monitoring and ensuring quality education is needed. A modernized digital learning ecosystem requires a renewed, shared understanding among leaders and stakeholders about an effective smart education model [5].

## II. MATERIAL AND METHOD

The material includes a review of scientific research of the smart cities and education as part of the quadruple helix model. The innovation process in education has been analyzed. The following scientific methods were used in the research process - analysis and synthesis, descriptive analysis.

## III. RESULTS AND DISCUSSION

### A. Smart cities and the Quadruple model perspective

Smart cities aim to improve the quality of life of citizens through the use of technology. However, the information and communication technologies are only part of the equation of smart cities development. "Social innovation, which creates new social forms and forms of cooperation in society, is also essential. In this context, the capacity of municipalities to involve the various stakeholders

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(entrepreneurs, academics, non-governmental organisations and citizens) in planning and implementation processes should be emphasised, as well as their ability to agree on the best solutions for development, responsibilities and investments as a result of common efforts” [6].

The engagement of the main stakeholders – government, academia, business and society - could be analyzed, considering the Quadruple helix model (Fig. 1). The Quadruple helix concept is presented as an innovation environment where stakeholders create partnerships among business, society, government institutions and research organizations.

The government and public authorities in general, have the task to provide the appropriate legal framework, policies and strategies. The main leadership and funding should be provided by the industry. Research and educational institutions participate in the process with knowledge transfer and scientific research. End-users must be motivated to actively participate in the open innovation process feedback process.

✓ **Government.** The role of public actors is to facilitate interactions by providing arenas and funding. Modernizing the digital learning ecosystem must involve human capacity building strategy and public investments [7]. Smart cities are also closely related to regions and the regional innovation strategies. There is a variety of evidence and good practices confirming that the regions and the cities are of crucial importance in the innovations’ development process, by creating industrial clusters, competence centres, incubators, technological parks and various formal and informal innovation spaces. The successful regions and cities become European and global innovation centres, technological networks and value chains [8].

✓ **Academia.** The HEI’s can play a significant role in: unlocking the intellectual and financial resources; deal with the unemployment and low skills; accessible higher education; upgrading the skills and acquiring of new skills; employment opportunities. attracting talented students and staff; promoting exchanges; collaboration between universities and the private sector; knowledge exchange between researchers and business. Therefore, universities need to engage themselves in sustainable development activities, arrange workshops and projects in cooperation with private, public, and civil sectors, in order to offer students an experience in solving real-life problems [9].

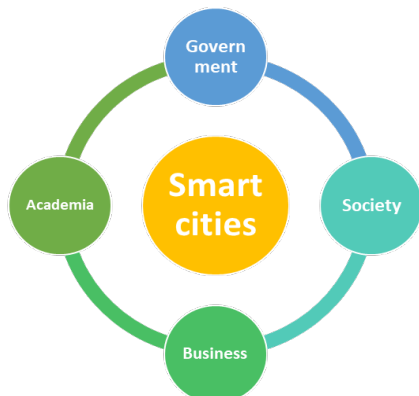


Fig. 1. Quadruple helix model, applied to smart cities.

✓ **Business.** Contributes with: regional partnerships; training and research consultancies; student placements; research incubators; using regional, national and European funding mechanisms; development of entrepreneurial skills; development of network and cluster organisations; development of intellectual property.

✓ **Society.** HEI’s could have a significant impact through delivering culture-based learning programmes, infrastructure (e.g. museums, galleries, music venues) and building infrastructure that improves and enhances the local area which in turn makes it more attractive to populations alike. Another important aspect is the building of vivid learning communities.

As part of the model, the personalized and on-demand service for teachers and students based on data interoperability is provided by the government and business. The last presents also a mechanism for collaborative innovation to promote the supply of open educational resources across regions for equal and inclusive education, while the new mode of educational governance will be empowered by AI and big data.

In regard to the quadruple helix model, the smart cities become real and actual “living labs”. Living labs are considered as a research approach where end-users are partners in the innovation process. Urban living labs function as an “explicit form of intervention” to intentionally contribute to the city sustainable development on the basis of “knowledge and learning” [10]. The phases of the innovation life cycle in living labs must be properly identified and managed, starting from the idea, the creation of products and services, and reaching the transfer of technology. From an organizational point of view, the living laboratory, in addition to the necessary infrastructure, financial and human resources, must have its own internal rules for management and functioning, including procedures for monitoring and active participation of end-users.

As the environment and environmental protection are essential part of the smart city concept, we could go further in conceptualizing the interconnections among the different model components. The Quintuple helix model builds on the quadruple, including our natural environment (Fig. 2). The connection between smart education, smart cities and environment, could be summarized as follows:

✓ **Environment.** Possible contribution: the Green Impact scheme; reducing waste and increasing recycling; increasing energy efficiency and reducing carbon emissions; increasing sustainable procurement; increasing sustainable transport; improving communications relating to sustainability; promotion of sustainable travel through public transport discounts and facilities and support for cyclists; satisfying the majority of the universities’ electricity needs from sustainable sources; researchers’ teams dealing with global issues; research in environmental sciences; sustainability as a guiding principle.

The smart city concept will evolve in the future and the next development stage will be “knowledge-based city”. That is why the knowledge and education will gain even more importance. Knowledge-based city will be the basis for sustainable development, accentuating the significant process of “transforming knowledge resources into local development” [11].

### B. Education in the context of the smart cities

Education is one of the areas of focus in smart cities because it is recognized as a crucial factor in empowering citizens and facilitating their more active role in various initiatives to make cities smart [12]. The presence of creative thinking and an appropriate level of education are among the factors that correlate with urban intelligence, which is why cities cannot achieve intelligence without creativity, education, knowledge and learning [13]. Smart education is a broad term for learning in today's digital age that reflects how advanced technology enables learners to acquire knowledge and skills more effectively, efficiently and conveniently. Education 4.0 refers to the future design and vision of learning, using the "digital technologies, personalized data, open-source content, connectivity" [14], developing creativity and innovative thinking. Modern education must be compatible with the knowledge and technological progress, required in smart cities. Purposeful change should make learning more interesting, collaborative and oriented towards the development of talents and skills, allowing students to solve different problems [15]. Smart education must accommodate the uniqueness of learners and provide more freedom in terms of pace and access to data and learning resources. This is only possible if the learning content and the teaching methods used are changed. Smart education is a learning model adapted to new generations of digital learners. Compared to traditional classroom teaching models, smart education is an interactive, collaborative, and visual model designed to increase student engagement and enable teachers to adapt to students' learning skills, interests, and preferences [16]. The digitalization of education has become a necessity in the last few years. Distance learning in an electronic environment during the two-year COVID-19 pandemic further strengthened the digitalization of educational processes.



Fig. 2. Quintuple helix model, applied to smart cities.

By complementing traditional education with e-learning, the use of learning management systems and e-learning platforms have become the standard for educational institutions, especially in higher education [17]. Although the pandemic situation is now a part of our past, improved e-learning practices in the learning process are undergoing further development and e-learning has entered its next, more mature stage [18]. The introduction of artificial intelligence (AI), augmented reality (AR) and virtual reality (VR) in education will become compulsory in the near future. Smart learning is related to the use of modern technologies for teaching and evaluating the

acquired knowledge. Despite its proximity, smart education should not be equated with digital education, because its essence is advanced digital education and its characteristics are related to more adaptation of the learning content and teaching effectiveness, compared to the characteristics of modern students. Smart learning is about learning in interactive, intelligent and personalized learning environments, including, augmented reality, cloud computing and social networking services.

The key elements in planning and developing smart education are: upgrading ICT infrastructure for education (e.g., broadband network, 5G, Wi-fi) and upgrading smart campuses with cyber and physical spaces (e.g., AI, IoT, VR/AR laboratories; data visualization; deploying security facilities). 5G technology integrates with the Internet of things, big data, AI, machine learning, etc. to serve the field of education and promote the development of smart education.

An example of the connection between smart cities and education are two of the "5G projects for smart communities" financed by the European Commission. The construction of a 5G mobile network (MPN) is supporting new functional approaches to education and training at universities and hospitals in Palermo, Italy and the University Hospital of Frankfurt in Germany to create a sustainable healthcare system, optimize learning and training processes of students and innovative solutions for monitoring and organizing hospital logistics.

### C. Innovations and technologies in the education

The development of technologies makes them an increasingly important part of education, as the use of ICT tools in the learning process allows combining technologies with modern teaching methods and tools. Technological equipment (hardware and software) and various ICT means are used in training and education.

The use of ICT tools in the educational process allows not only to motivate students for active participation in the learning process, but also encourages their desire to continuously seek new knowledge and self-improvement. The development of technologies and their entry into education leads to the creation of new teaching methods, such as:

- Virtual classroom - where the learning process is organized in electronic form. The virtual classroom allows the teacher to share learning content, provide additional learning resources, communicate with students, assess their knowledge, and conduct online meetings in real time. The use of virtual classrooms increased by 3600% in the month of March 2020 and by 9000% at the end of the month of September 2020 [19]. This process has been largely driven by the shift to online learning courses, but the use of e-learning platforms and students' use of alternative learning content formats has also increased dramatically.

- Video conference meeting - cloud technologies allow synchronous learning and video conference connection between teacher and students. Such technologies and tools are Google Hangouts/Google Meets, Microsoft Teams/Meets, Zoom, etc.

- Shared Classroom - Virtual classroom functionality that allows content to be shared with another teacher or

students. It can be used when conducting a lesson on one topic in several school classes or when conducting interdisciplinary lessons.

- Flipped classroom - the specificity of using a flipped classroom is that the conduct of a typical lesson and the assignment of homework assignments are switched. The method is based on cloud technologies, and the provision of learning materials by the teacher to students is carried out by sharing them as text and audio files or using resources from a created virtual classroom. When using the method, links (hyperlinks) that the teacher provides to the students and that contain information related to the studied content can also be used.

- Project-based learning in an electronic environment – learning that is personally oriented and aims to acquire new knowledge through the manifestation of creativity on the part of students. Activities included include independent information seeking, content research and evaluation, learning project development, and more. The main elements of project-based learning are searching and retrieving information, critically evaluating information resources in the online space, and performing team tasks. The training provides an opportunity to acquire knowledge by finding a solution and researching a given question, using interactive means to visualize the content presented by the students.

- Multi-Media Text Sets – a method where all learning resources on a specific topic are organized in one place and made accessible to students. The learning resources used can be in different formats – text files, presentations, audio and video files.

ICT-based teaching methods allow attracting the interest of students, easier mastery of knowledge and its permanent assimilation. Through ICT means, the teacher can apply a metacognitive approach in teaching, aimed at mastering knowledge, skills and competences through analysis, reflection and self-improvement. Internet and ICT-based methods allow various opportunities for their use in education, being constantly developed and enriched.

Technology is the intersection of smart cities and education, and their dependence is growing, and two main dimensions can be distinguished. The first is in the context of remote access to resources, tools and technologies via Internet, and the second is the training of experts for the development of smart cities themselves. In one of the fastest growing universities in Bulgaria - the University of Telecommunications and Post, a variety of platforms and applications are used in students' training, especially in the field of Engineering. Table 1 includes the main ones, based on various modern technologies - cloud computing for data storage, peer-to-peer for video communication, container-based for writing code and immediate execution, and others. Practice shows that they improve the efficiency, flexibility and productivity of the educational process.

Technological developments also require the creation and updating of an appropriate legal framework, including on digital learning content and digital competence. Regarding the digital skills of teachers at all levels of education, the European Commission's Digital Competence Framework for Teachers (Dig Comp Edu) [20] defines and describes the skills that teachers should

acquire in order to teach and introduce innovations through the use of digital technologies.

The digital transformation requires the adoption of standards for digital learning content creation and strategy for improving the digital competence, both for teachers and students. A mechanism and more efforts are needed in order to promote, both teachers' and students' digital literacy, awareness, computational thinking, digital learning and information social responsibility, through relevant curriculum and practice. According to the European Commission "digital competence" refers to "effectively and critically use information and technology for training, self-development and active participation in society [20]". The Dig Comp framework 2.2. encompasses 5 different areas: Information and data literacy; communication and collaboration; digital content creation; safety; problem solving.

TABLE 1 USE OF ICT'S IN EDUCATION

Application	Type of technology, use and discipline		
	Technology	Use	Discipline
Google Drive	Cloud computing	Data storage	All disciplines
Unicloud.utp.bg	Cloud computing	Data storage	All disciplines
Zoom	Peer-to-peer	Video conference	All disciplines
Github	Git	Developer community	Software quality assurance
Pastebin	Content-hosting	Code sharing	Fundamentals of programming
W3schools	Content-hosting	Training	Fundamentals of programming
Python.org	Content-hosting	Training	Fundamentals of programming
Sololearn	Content-hosting	Training	Object-oriented design
Learn SQL	Content-hosting	Training	Databases
Replit	Browser based	REPL / IDE	Object-oriented design
SQL Online	Browser based	IDE	Databases
Online Python	Browser based	IDE	Object-oriented design
Jira	Browser based	Project Management	Software quality assurance

The digital competence of the academic staff and students significantly influences the introduction of new technologies in education by harmonizing digital learning methods, intercultural interaction and equal access to higher education.

#### D. Opportunities and challenges

In the modern educational process, information and communication technologies are not the only object of study, but a means through which the educational process is implemented. The wide penetration of technologies in the whole society, turn them into a tool used by students, even from the initial stage, which requires updating the way of teaching the learning content to increase learning motivation. The use of ICT tools in the teaching of individual subjects allows not only to increase the motivation of the students, but also the acquisition of digital competences and the achievement of digital literacy. The



variety of ICT-based teaching methods and the effectiveness of their use confirm the fact that in a digital environment, students' knowledge is mastered more easily, while being durable and functional, and the educational process is defined as conscious and motivated. The use of ICT solutions provides conditions for the application of a metacognitive approach in teaching, through which students' attention is directed to mastering competencies through reflection, analysis and self-improvement.

Along with these opportunities, there are some challenges for integrating emerging ICT technologies into teaching and learning, e.g. inclusion and equality problems, technology governance, ethics, accountability, transparency and security of smart technologies, etc. The challenges of introducing smart education are caused by the lack of sufficient ICT resources in various educational institutions and need for digital literacy improvement. The above basic digital skills provide new opportunities for obtaining information by students, promoting independent learning, research and analysis of various information sources. At all levels of the educational system, the benefits of using digitization in the learning process include also intellectual, mental and emotional aspects. Social-emotional skills, such as self-awareness, self-management, social awareness, relationship skills (and responsible decision-making skills will be crucial in the digital age.

The solution to these challenges could be found in the quadruple helix model - in an effective collaboration among government, business, academia and society.

#### *E. Policies and strategies*

Innovations in the field of education have been born out of the development of modern society and the technological revolution. Revolutions 4.0 and 5.0 are bringing more and more products and services based on robotics, artificial intelligence, the Internet of Things (IoT) and big databases into everyday life. It is increasingly assumed that today's students will work in occupations that do not yet exist. Future professions require new knowledge and competences, which should be provided to learners through an innovative approach in education, to promote the acquisition of different competences and creative thinking. It is necessary to make sustainable reforms in order to achieve smart education, in view of the interests of modern students and technological progress.

Due to the COVID-19 pandemic and the consequent, unprecedented expansion of remote and online learning models, education leaders have recognized the urgency to modernize the digital learning ecosystem in order to provide inclusive and equitable educational opportunities to all students in the new era. Public authorities have a key role in the process of deploying, maintaining and updating the necessary infrastructure, as well as in establishing criteria and guidance around creating or curating quality digital educational resources. Another important political aspect is the adoption of a legal framework for the protection of personal information. In this regard, a proper mechanism for safety of networks and connection should be provided. The policies and strategies should ensure the full participation and inclusion of people regardless of their ethnicity, origin, cultural and religious identity, gender, age, socioeconomic status, physical ability or

other criteria that may lead to the marginalization of certain populations. Smart learning environments have the ability to provide just-in-time learning that is based on the broad capabilities and levels of adaptation and greater specification of student learning conditions [21]. The role of smart education is to support learners in the 21st century to meet and successfully cope with the challenges of a digitalized society, including developing the ability for problem-solving [22].

With regard to the twin transition, European Commission aims at "adapting education and training systems to match a rapidly transforming technological and socio-economic reality as well as supporting labour mobility across sectors" [23]. A complete revision of the curricula, the training methods and the possibilities of new technologies should be done. The development of a smart education plan for teaching and learning will promote the ability of learners, educators and citizens to adapt to an uncertain, complex and ever-changing world. Therefore, the strategical incentives for multi-sector partnerships will be crucial for contributing and sharing the knowledge and resources for the public good.

#### IV. CONCLUSION

The innovation process of the smart education is related to the "new era transition process", along with the preparation of the students as lifelong, empowered learners, ready to rapidly adapt to the labour market. Therefore, a strategy for collaborative innovation to promote the supply of open educational resources across regions for equal and inclusive education is needed. All the stakeholders – government, academy, business and society - should interact in the process of educational modernization.

Smart education has become an important strategy for building a smart society and is an essential part of the quadruple helix model, applied to smart cities. It is important to provide the necessary mechanisms and approaches for promoting both teachers' and students' digital literacy, awareness, computational thinking, digital learning and information social responsibility through relevant curriculum and practice. The innovative teaching methods and strategies such as hybrid education, learning and assessment, support the deep infusion of ICT into education. Like any other ecosystem in nature, the educational ecosystem needs balance to be sustainable. By the use of technologies and innovation, the modern educational institutions could promote not only student satisfaction with the learning process, but also support the development of smart and knowledge-based cities.

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