# CURRENT STUDIES IN TECHNOLOGY, INNOVATION AND ENTREPRENEURSHIP

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ISRES Publishing

# Current Studies in Technology, Innovation and Entrepreneurship

Editors, Cover Design and Layout

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## PREFACE

This book was prepared from the selected academic research and review studies invited by the editors. It was focused on the issues based on "Current Studies in Technology, Innovation and Entrepreneurship" under the leadership of The International Society for Research in Education and Science (ISRES) Publishing which is the status of Recognized International Publishing. In addition, all submissions were reviewed by at least two international referees and composed of 10 chapters (20 authors in total) selected by the editors. The purpose of the book is to provide the readers with the opportunity of a scholarly refereed publication in the field of Technology, Innovation, and Entrepreneurship. Finally, we hope the book will present curiosity in this field, the book will be useful for new scientists, science readers, and anyone who intends to learn about the mystery of science.

**December, 2023**

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CHAPTER

# Emerging Assistive Technologies and Challenges Encountered

1

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## Introduction

According to the World Health Organization (WHO) and its International Classification of Functioning Disability and Health (ICF), disability is an umbrella term encompassing impairments, activity limitations and participation restrictions (WHO, 2001, p. 213). The WHO considers that disability as the result of the interactions between health conditions (such as diseases, disorders, and injuries) and various contextual factors. Contextual factors may include external environmental factors such as legal attitudes, social attitudes, climate etc. as well as internal personal factors like gender, age, education, behavior pattern, and so forth and also other factors that influence how a person experiences disability (WHO, 2002, p. 10). Disability should not be viewed as a clear-cut situation; instead, it exists on a spectrum defined by the interaction between the individual and their environment. As a result, whether a particular condition qualifies as a disability or not hinges on the environmental and societal obstacles that an individual, with their unique characteristics, must confront (Nierling et al., 2018, p. 11). The fact that disability is not only health-based but also has many causes makes the definition of "disability" multidimensional and complex.

As stated by the World Health Organization, 15% of the world's population, approximately 190 million people, have different types of disabilities and 2-4% of the total population have major functional difficulties. It is predicted that disability rates will increase due to the aging of the world population and the emergence of chronic diseases (WHO & World Bank, 2011, p. 44). Between 2020 and 2030, the global population of individuals aged 60 and above is projected to increase from 901 million to 1.4 billion. By 2050, this number is anticipated to double to nearly 2.1 billion. Projections suggest that by 2050, the population of individuals aged 80 and above will reach 434 million, which is three times the current number of people in that age group. While many older individuals will enjoy good health, the prevalence of disability is also expected to rise proportionally, posing a significant challenge to healthcare systems (Millana et al., 2020, p. 2).

Disability encompasses a diverse range of people. Some are born with it, while others result from accidents, injuries, or chronic illnesses. Additionally, disability that occurs in the later stages of life is among the most common. People's health needs and the tools they need to use may vary depending on their disability. Since there are various restrictions, a tailor-made healthcare service may be required. Since this situation can sometimes lead to high health needs, the way disability is addressed has begun to shift from a medical approach to an approach that increases individuals' well-being and functionality (Scholz, 2015, p. 1). Assistive devices and applications serve as support for disabled people to survive, become productive individuals in society, and contribute to their social, cultural and economic lives. Many traditional mechanical devices are useful for daily activities and are also preferred by some disabled people. However, everyone's disability and living conditions differ. Many people may have more than one disability at different levels and therefore need different levels of care. On the other hand, the social and economic situation of these people, the extent to which they need to participate in business and education life, their life habits, expectations and demands may also differ. In addition, with the diversity and advancement of technology, classical and traditional devices have become insufficient for disabled individuals to become productive in society. With developing technology, researchers and entrepreneurs have started to search for more technological assistive devices suitable for disabled individuals.

According to WHO (2022, p. 6) "an assistive product is any external product (including devices, equipment, instruments or software), especially produced or generally available, with the primary purpose of maintaining or improving an individual's functioning and independence, thereby promoting their well-being. Assistive products are also used to prevent impairments and secondary health conditions. Similarly, the definition of an assistive product by ISO 9999:2011 is "Any product (including devices, equipment, instruments, and software), specially produced or generally available, used by or for persons with disabilities for participation; to protect, support, train, measure, or substitute for body functions/structures and activities; or to prevent impairments, activity limitations, or participation restrictions" (Scholz, 2015, p. 4). Assistive products include physical items like wheelchairs, glasses, hearing aids, dentures, walking aids, etc. They also encompass software and applications in digital form, which strengthen interpersonal communication, provide quick access to information, support education and training, etc. In conclusion, an assistive product serves as a bridge between an individual and the life they aspire to lead. Technology lies behind the emergence of assistive products. That we can call "Assistive Technology (AT)". AT provide the opportunity for elderly individuals, disabled people, and people with medical conditions or injuries to live an independent life by making their lives easier. AT plays a major role in enabling individuals to be more productive, receive education, and participate in the workforce and society. Today's technological developments have also accelerated the development of ATs. AT products integrated with today's most up-to-date technologies such as Artificial Intelligence (AI), sensor and wearable technology, IoT, virtual-augmented and mixed reality, robotics, and brain-computer interface have gradually begun to take a place in the lives of disabled individuals.

## The Aim of the Research

This study encompasses a conceptual exploration AT, aiming to shed light on the extent of technological advancements by providing examples of some products, services, and applications. Recognizing the anticipated increase in the need for AT in the coming years, the research also aims to raise awareness within society and keep individuals informed about the development of AT. Although having access to AT is considered a “human right” for people with disabilities, the study addresses challenges related to AT, emphasizing the need to resolve these issues. The paper discusses these challenges and provides solutions as well.

## Assistive Technology Concept

Technology has the effect of making life easier, speeding up work, and providing all kinds of access to information. The technology that surrounds us is an indispensable part of our daily lives. While having technology is important, it is equally crucial to choose the right technology for the activities we want and need. What matters most is the individual’s use of enabling technologies, their experience, and satisfaction level. At this point, having AT becomes very important, as it has a facilitating effect on the lives of disabled individuals.

The concept of AT has been extensively employed across various domains over the years. One of the initial official definitions of AT was enshrined in the Technology-Related Assistance for Individuals with Disabilities Act. This legislation, initially enacted in 1988, reauthorized in 1994, and reintroduced in 1998 (Golden, 2011), outlines AT as encompassing any item, equipment, or customized product system, whether commercially obtained or modified, aimed at enhancing, maintaining, or improving the functional capabilities of individuals with disabilities. Furthermore, the act underscores the significance of AT services, denoting any service directly aiding an individual with a disability in the selection, acquisition, or utilization of an AT device. AT isn’t solely designed to enhance capabilities for individuals with disabilities but can also assist others, such as family members and caregivers, in performing daily tasks associated with instrumental activities of daily living, including education, work, and social and cultural engagements (Alper & Raharinirina, 2006, p. 47-48).

According to the WHO organization, AT is assistive items, services and systems used to maintain or restore an individual’s functionality and increase their level of well-being. The Assistive Technology Industry Association provides a definition for AT that products and services as any object, device, piece of hardware, or software designed to aid individuals dealing with various forms of disabilities. AT includes a range of services, products, methods, approaches, and techniques designed to reduce or remove the barriers and constraints faced by individuals with disabilities or impairments (Fall et al., 2017, p. 967). AT enables individuals to do jobs that they cannot do or make them easier to do. In this sense, AT has the status of special products that help disabled people to compensate for the freedoms they have lost or feel deficient in, and can include any product, device, application or software. By making the lives of disabled individuals easier and safer, AT can reduce not only their freedom but also their need for others. AT offers individuals the opportunity to be active in education, business and social environments with ease and self-confidence. According to Aqel et al (2019, p. 17) without AT, individuals with disabilities are excluded from society, isolated and condemned to poverty. This increases the negative impact of disability on families and society. In fact, according to Wolbring (2011, p. 611) there are still debates regarding whether a device that goes beyond a ‘normal’ human is considered an AT within the definition of AT’s.

As per the 2018 report from the WHO over one billion people worldwide require AT, yet only one out of every ten individuals have access to the necessary products. By 2030, this substantial number is expected to double, reaching the threshold of two billion. According to WHO (2022) for a more detailed breakdown of the current global AT requirements. This includes 970 million individuals in need of eyeglasses and low vision aids, 75 million who require wheelchairs, 150 million in need of mobility aids, 35 million seeking prostheses and orthoses, 94 million who could benefit from hearing aids, and 150 million individuals requiring cognitive aids (Aqel et. al., 2019, p. 16).

AT has become a growing field with the advancement of digital technology and the constant change of needs. Especially with the aging of the world population, the interest in AT has increased both for users and has become an area of opportunity for businesses (WHO, 2022). AT can support individuals in accessing their human rights. With the help of AT people with disabilities can achieve the fundamental human right of participating in all aspects of society. The development of technology has changed everyone's life, but it is especially important for disabled individuals. Because it often helps disabled people find and maintain employment. According to the National Disability Authority (2005) report, 85% of disabilities are acquired during working life. When individuals with disabilities cannot access such technologies, employment and career advancement are compromised (DFI, 2016).

AT, regardless of device complexity, can compensate for sensory, physical/mobility, and cognitive impairments and aims to maintain or enhance individuals' functionality, helping them achieve a better quality of life (Lancioni & Singh, 2014; Boucher, 2018). There are a wide variety of Low Tech or High tech ATs available (Marino et al., 2006, p. 21). These products vary in technological complexity and detail. Low-tech products are equipment or tools that are more affordable, do not require much training and preparation to use, and have simple mechanical features. Large print, walkers, canes, etc. may be in this category. High-tech ATs, on the other hand, are computer-based, costly products that have complex electronic components and require training before use. Devices that produce private speech, shoes that recognize obstacles and determine routes, home automation systems, etc. High-tech devices have diversified, especially with the development of mobile phones and software.

## Literature Review

There are many areas where AT are used. AT has a wide range of uses in autism, emotional and behavioral disorders, intellectual, physical, speech and learning disabilities, traumatic brain injuries, blind and vision impaired, deaf and hearing problems, and the elderly. Many studies have been conducted in the literature related to AT. These include research focusing on specific disabilities, as well as studies that address methodological approaches or have a conceptual nature. The following mentioned studies encompass only those that specifically revolve around the development of products, services, or applications related to AT and those addressing the challenges associated with AT.

AT are very helpful tools in the rehabilitation process for individuals with autism. AT can play an active role in improving social, functional and communication skills and repetitive behaviors in individuals with autism. Chen et al (2016); Parsons (2016); Law et al (2018); Hussain et al (2016); Kandalaft et al (2013) have enriched their contributions to individuals with autism with examples of AT products such as augmented and Virtual Reality (VR), mobile learning and educational entertainment. There are many ATs that have been developed for individuals who are blind or have limited vision so that they can find their way, go where they want, and know what products and services they may need. With the development of mobile technology, many applications are available in addition to the tools used. Tapu et al (2014); Manjari et al (2020) researched wearable products used for visually impaired individuals to navigate outdoors. By developing an obstacle avoidance system, Zahn & Khan (2022) sets an example of technologies that provide greater independence for the visually impaired. Xiao et al (2021) developed a guide robot dog model that helps visually impaired people find their way. Júnior et al (2019) have presented a framework that uses machine learning and computer vision techniques to use an IoT device to identify objects, measure distances, and transmit information to a visually impaired individual. Chang et al (2019) developed a deep learning-based wearable drug recognition system. Zainuddin et al (2010) conducted an augmented reality application called AR-Book for the use of hearing-impaired students. Lin et al (2018) and Chern et al (2017) propose a mobile phone-based hearing aid system (SmartHear) that uses wireless technologies for those with hearing loss. Thinh et al (2017) discuss a robot developed to translate spoken language texts into sign languages. Rashid et al (2017) and Sai et al (2017) designed a system to control the devices in the house by using voice commands and sensor technology to turn on and off some devices in the house (such as opening and closing doors). Burleson et al (2015) introduced DRESS, a computer vision system that facilitates the dressing process for Dementia patients and will help the dressing process without a caregiver. VR technology can also be successful in recalling old memories. A study conducted by Benoit et al (2015) suggests that VR can assist in memory recall in elderly individuals. Scholz (2015) included examples of AT developed for individuals with visual, hearing, cognitive, communication and motor disabilities.

Das et al (2017) examined the IoT approaches recommended and designed especially for elderly individuals and the challenges related to IoT use. Cruz et al (2016) conducted research in private and public rehab centers to determine the difficulties experienced in the use of AT by therapists working with disabled people and in accessing these technologies. In their research, Steel et al (2016) discussed challenges to AT use at the level of interaction between practitioners and consumers, and challenges at the level of markets and policies. 3D printing, which can be considered as one of the AT products, has a great place especially in rehabilitation and physical therapy. In this sense, Mcdonald et al (2016) conducted a study to identify the opportunities and obstacles of 3D printing in the field of physical therapy. Demirok et al (2019) and Kutlu et al (2018) conducted research to determine the attitudes of special education teachers towards the use of AT. Contepomi (2019) discussed the various opportunities and obstacles to providing adequate access to AT in Argentina.

## Emerging Assistive Technologies

Today, we observe widespread access to innovative high-tech solutions across various fields. According to WHO (2022) report, while future innovative applications may reach an advanced level, it is noted that the majority of people with disabilities will have simpler needs for assistive products. However, with the continuous advancement of technology, the utilization of high-tech solutions is likely to become prevalent in various professions, benefiting people across different walks of life. Consequently, individuals will need to adapt to these innovative applications in the near future. People with disabilities, in particular, will require high-tech assistive products that can seamlessly adapt to these evolving technologies.

Advanced sensors, AI, and IoT are propelling the transformation of traditional AT into ‘smart’ assistive products. Sensor technology is leveraged in many smart products such as walking aids and wheelchairs that incorporate lightweight detection sensors. Additionally, there are numerous assistive products that result from the convergence of multiple technologies. For example, medication dispensers are connected to IoT/sensors or integrated with AI systems for medication management. Moreover, there are both wearable (smart clothing, lenses, wristbands, watches) and non-wearable devices (smart carpets and mirrors) that utilize sensors, AI, machine learning, IoT, and cloud connectivity for monitoring health and emotions.

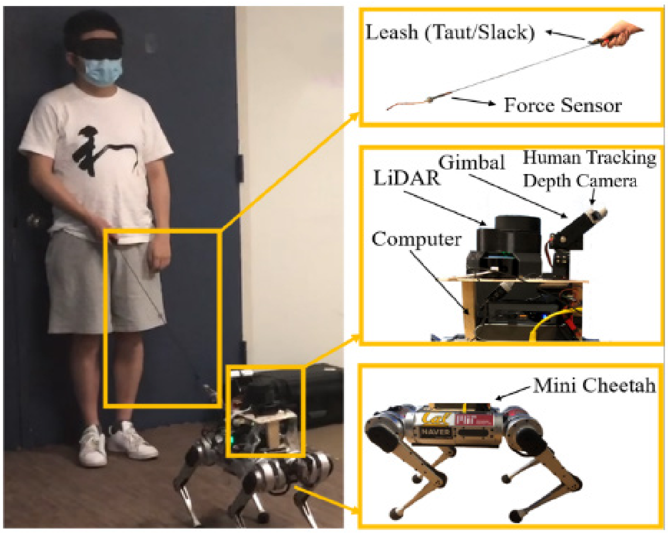
The report prepared by WIPO (2021) mentions emerging technologies in the AT field. These can be; AI, IoT, brain-computer interfaces, sensor technology, robotics, advances in computing, VR/augmented reality and connectivity; additive manufacturing; new materials and Autonomous vehicles. Although the products, services and applications given below are classified according to the technologies used, it should be remembered that the examples mentioned do not only use the specified technology. Many ATs have devices produced using more than one technology. Therefore, for example, products promoted under AI technology can contain sensor technology, IoT, Robotics etc.

## Robotic Assistive Technologies

One of the fastest-developing technology is robotics which also has a significant impact on the socio-economics field. Robotic applications are finding their place in healthcare, education, and social environments, serving a wide range of purposes. These include caring for and educating children with autism, as well as children and individuals with physical disabilities. Additionally, robots provide companionship for older persons with dementia and are utilized for rehabilitation and training (Bemelmans et al., 2015; Bedaf et al., 2017). Among the most promising developments are assistive robots, autonomous systems capable of 'living' with individuals and assisting in all daily life activities such as dressing, toileting, eating, interpersonal interaction, and more (Huijnen et al., 2019). These robots provide physical assistance, including robotic wheelchairs, and social assistance robots designed to address socio-emotional needs, are commonly used in elderly and cognitively impaired populations. Social assistance robots are equipped with a social interface to facilitate interaction with users (Yu, et al., 2022, p. 2). With the elderly population steadily increasing and projected to double by 2050, reaching a level of 2.1 billion, the demand for these robots is expected to grow even further.

Instead of traditional sensor-equipped canes, a robot called **CANINE,** functions as a cane-like mobile assistant, especially for the elderly and individuals with balance and visual impairments. By autonomously following the user, it allows them to maintain a coordinated and attentive-free movement (Stramel et al., 2019, p. 4139-4140). CANINE is a robotic cane connected to a mobile robot that automatically tracks and moves alongside a walking individual, essentially serving as a type of mobile assistant. **KASPAR** is a robotic assistant designed as a social companion for children with autism, is a child-sized humanoid robot. It aims to support teachers and parents in helping children with autism overcome the challenges they face in socializing and communicating with others. KASPAR facilitate therapy games with children of autism and communication difficulties, and it helps identify their emotions and stress levels during these games. With Kaspar, children with autism play therapy games, and through various smart sensors, it tracks eye movements, facial expressions, sound, and posture. Research shows that Kaspar encourages collaboration among children, extends their attention spans, promotes social interaction among children, and helps them learn about body parts (Wainer et al., 2014). Guide dogs are of vital importance for helping visually impaired individuals navigate their surroundings. However, raising and caring for guide dogs can be quite challenging for disabled individuals. Today, there are guide dog robots developed under different names. One of these robots has been created at the University of Berkeley. **The Mini Cheetah** is equipped with Lidar technology for environmental perception and a camera to detect the position of the person it is guiding. A visually impaired individual uses a special leash to understand which direction the robot dog is leading them. The leash, with one end attached to the robot dog, is equipped with sensors that can measure its own tension. This allows the robot dog to determine whether the leash is taut or loose. When robot dogs need to change direction during movement, they first take a few steps back to loosen the leash, signaling to the visually impaired person that they need to stop. After the robot determines the correct direction, it resumes moving, and the visually impaired person starts moving again when they sense the leash has tightened (Xiao et al., 2021).

**Figure 1**. *The Mini Cheetah*




**iBOT** is a specialized wheelchair device designed for individuals with limited mobility or who use a wheelchair. It can go up and down stairs with its self-balancing technology. It is a very useful assistive device for the physically disabled with its ability to convert from four wheels to two wheels, height adjustment and climbing stairs. Similarly, **TopChair-S and Scewo** are other assistive devices that use robotic and sensor technologies. **Honda Walking Assist (HWA)** is an exoskeleton type robot, helps individuals living with walking difficulties. The control computer initiates motor activation using information acquired from hip angle sensors while walking. This is done to enhance the synchronization of each leg's lift-off and forward extension, thereby facilitating a more balanced and smoother gait with an increased stride length for easier walking. Studies show that patients using HWA achieve significant improvement in their walking functions with long-term use.

**Figure 2.** *Honda Walking Assist*

## Artificial Intelligence Based Assistive Technology

The term "AI" was introduced by John McCarthy, regarded as the pioneer of AI, in 1956, during the first AI conference held at Dartmouth College. McCarthy's definition characterizes AI as the science and engineering focused on creating intelligent machines, particularly intelligent computer programs. AI is used in many areas today. In health, energy, telecommunications, vehicles, telephones, etc. AI is also used in many of the high-level AT developed for the disabled. AI technique is widely used to enable or facilitate the daily activities of people with vision, speech, hearing, cognitive disorders and movement disorders. Other AI technologies such as machine learning, 3D printing, deep learning, natural language processing, artificial neural networks have high potential in the development of AT tools. The recent growth in the field of AI can be attributed to deep learning, a technique that enables computers to perform complex human-like tasks such as speech recognition, image analysis, and object recognition (WIPO, 2021).

Sensor technology is not a new field, but there have been significant improvements in the last few years, allowing them to advance various technological fields. Advances in sensor technology have also enabled developments in wearable technology and the internet of things. In this section, sensor technology and AI applications are exemplified together.

**OrCam MyEye** is a good example of using AI technology to assist people with visually impaired disabilities. A wearable, voice-activated solution for individuals with visual impairments. It provides the ability to instantly read text from any book or screen, effortlessly recognize the faces of family and friends, and accurately identify various products, all in real-time communication with the user. Similarly, wearable devices such as **Horus, eSight** and **Aira** are offered to visually impaired individuals. These devices have the ability to identify what users are looking at using deep learning and object recognition methods.

**Figure 3.** *OrCAM, Horus and Aira*

*Source: (Bigumu, 2023)*

The AI-supported **WeWalk** smart cane, designed for the visually impaired by YGA (Young Guru Academy) and Vestel engineers in Turkey, has features aimed at enhancing individuals' mobility. WeWalk alerts the individual by vibrating about obstacles that might go unnoticed. By integrating with a smartphone, it provides voice feedback for finding the current location, navigating to new locations, and allows control over the device. It has the capability to integrate with mobile applications, enabling self-improvement features. A new project called **Feeling Fireworks** aims to make people who are blind or have low vision 'feel' fireworks. The project, offers a tactile fireworks show in which fountains are transferred to a flexible screen. Users extend their hands towards the screen. Kinect placed near the screen detects the user and the user feels tactile fireworks that resemble real fireworks exploding in the sky. Different heads produce different parts of the firework. Three caps produce the explosion effect, while another cap produces the crackling sound of a firework. Another title reveals the floral image created by fireworks (Reusser et al., 2017, p. 65 ).

**Figure 4.** *Feeling Fireworks*

**Feel The View**, developed for visually impaired individuals, is mounted on the car window, allowing them to feel the view. A camera is used to capture the view. It then converts the photo into a high-contrast grayscale image. With 225 different intensity levels, each shade of gray gives unique vibrations that enable the visually impaired passenger to feel what is outside by touch. There is also a voice assistant that provides detailed scene descriptions, which can be connected to the vehicle's audio system. The system is described on the Ford Europe blog as a smart window for the visually impaired (Bigumigu, 2023).

**Figure 5.** *Feel The View*

Advanced sensors and AI have succeeded in making traditional AT 'smart.' Both of these technologies are utilized in many assistive devices. Machine learning, a component of AI, is also used to develop smart glasses that detect distances between the user and objects in the environment to assist with navigation. The **Envision Glasses,** a smart eyewear for the visually impaired, can scan and read aloud everything, including handwritten text; it can recognize human faces, objects, and outdoor scenes. To support reading in over 60 languages, the Envision Glasses utilize AI. The device can also provide detailed descriptions of outdoor scenes to the user. It enables private and secure video calls with trusted users. Additional features include color detection, light detection, object recognition, and face recognition. With the object recognition feature, users can keep track of their belongings and find them whenever needed (Envision Glasses, 2023). **Liftware** is an electronic fork and spoon designed for individuals with Parkinson's disease and other movement disorders. Regardless of how much the hand moves while eating, it ensures that the food does not spill with its stabilizing head. **Carbonhand** stands as a groundbreaking assistance tool, restoring empowerment to individuals with impaired hand function (Bioserve, 2023). Utilizing pressure sensors and cutting-edge technology, this glove provides additional strength when the user's natural muscle strength falls short. Functioning as a beneficial aid, Carbonhand takes the shape of a grip-enhancing glove equipped with pressure sensors on the fingers, capable of identifying moments when the user requires additional support. **Neural Sleeve** leg, a wearable technology product brought to life with CIONIC's AI supported technology; It promises independence for those who have movement restrictions such as sclerosis, stroke, cerebral palsy. It uses AI and functional electrical stimulation through electrodes to promote leg movement and smoother walking (Neural Sleeve, 2023). A different protective headgear called **Hear Gear** was developed in order to create an egalitarian environment in sports by helping sports people with hearing problems. The protective headgear which has a special technology, absorbs impacts while also allowing people with hearing problems to hear without any problems with its built-in hearing implants.

Individuals who used hearing aids during sports could not hear due to the headgear. This problem is overcome with HearGear (Bigumu, 2023). For visually impaired people, walking outside can be stressful and unsafe, especially in big cities. Passing among people in a crowded place or moving depending on someone or a living creature (guide dog) can limit a person. Biped guides the person with intuitive feedback for the visually impaired; aims to eliminate this problem. The 3D infrared camera located in front of the AI-supported device placed on the user's shoulder can take images at a 170-degree angle. AI-based software notifies the user of fixed or moving objects in the environment a few seconds in advance through spatial sounds.

**Figure 6.** *Carbonhand and Neural Sleeve*

## Wearable Assistive Technology

The effects and applications of wearable technology are very extensive. It can impact fields such as healthcare, medicine, fitness, aging, disability, education, transportation, business, finance, gaming, and music. In each of these areas, the goal of wearable technologies is to seamlessly integrate functional, portable electronics and computers into individuals' daily lives. One of the most significant features of wearable technology is the ability to connect to the internet and exchange data between the device and the network. This capability for both sending and receiving data is facilitated in wearable technology through the IoT. Today, wearable technologies stand out as the widespread use of augmented reality technologies. In this sense, many companies have developed wearable technologies in the form of glasses, headgear or helmets, watches, t-shirts, shoes and even jewelry.

One of the fundamental factors that make life difficult for individuals with hearing impairments is that not everyone knows sign language. The smart glove **Sign-IO,** which can convert sign language into spoken speech, reduces this barrier through sensors on each finger that translate finger movements into letters. This way, when a hearing-impaired user communicates using sign language, their finger movements are measured accurately, and they are connected to a mobile application via Bluetooth to enable the other party to understand them. **SilentWakeUp** is able to wake up users who are hearing impaired or have difficulty hearing. This wearable watch, measuring 1 x 3 x 5 cm, adheres to the user's body through medical-grade adhesive pads. The system connects to a smartphone application via Bluetooth. Users can set their wake-up time on the smartphone. SilentWakeUp starts vibrating gently 10 minutes before the alarm time. Then, the vibrations gradually intensify. Depending on how deeply the user is asleep, the system can be adjusted to three different vibration levels. **The Sound Shirt** is a wearable technology product developed specifically to enhance the auditory experience for individuals with hearing impairments. It translates sounds into vibrations for the hearing-impaired. The software integrated into the Sound Shirt is capable of translating 8 different types of sounds, including bass, cello, horn, and percussion. Data is sent to the garment via a wireless system, and the intensity of the music is also detected, then converted into vibrations by 16 micro actuators on the garment. **Sunu Band** is the first smart bracelet that enhances mobility and independence for visually impaired individuals using Sunu-ultrasonic wearable technology. With this device, disabled individuals can feel and navigate their surroundings without physical contact. It provides notifications to the user via vibrations when it detects an object or a person at a distance of approximately 4.5 meters. **Vizorro** is a compact wearable laser navigation device that measures the distance to any obstacle pointed by the user. This unique device employs the principle of sensory extension, allowing blind individuals to sense the distance to various obstacles in their surroundings. Vizorro can be directed in different directions and aids the user in scanning their environment for obstacles (Alabi & Mutula, 2020, p. 14).

**Figure 7.** *The Sound Shirt*

**Google Glass** is a wearable assistive device that can help autistic children analyze their emotional states. With the use of specialized applications or software, the device can introduce facial expressions, emotional tones, and other social cues to assist autistic individuals in improving their interaction skills. The device can also control sound and light settings through specialized software and sensors to create a comfortable environment for autistic individuals. The system recognizes seven facial expressions happiness, anger, surprise, sadness, fear, disgust, and contempt (Haber et al., 2020, p. 49). **Dot** is the world's first Braille smartwatch. Dot assists visually impaired individuals in tasks such as accessing messages, sending tweets, using social media, and sending email.

**Figure 8.** *Dot*

## Assistive Software and Applications

**Seeing AI** is an AI application developed by Microsoft, specifically designed for individuals with visual impairments. . It is a free application that encompasses various functions, including short text, document, product, person, scene, currency, light, color, and handwriting recognition. Some of its features include reading text captured by the camera, using beep sounds to guide users to products, scanning product barcodes, predicting people's ages, genders, and facial expressions, saving people's faces, recognizing paper currency, reading handwriting such as on greeting cards, describing images in Mail, Photos, Twitter, and more. This application aims to provide convenience for individuals with visual impairments, offering features such as listening to descriptions of stored photos on the device and recognizing people, along with guessing the age and emotional state of strangers (Seeing AI, 2023). **Be My Eyes** is an application where blind and sighted volunteers are brought together. This application provides vision for the visually impaired by using the power of technology and human relations. Finding lost items, a problem with the computer while grocery shopping, reading labels, using different items, etc. can be used for aid. In other words, their work is done without having to wait until a sighted person arrives. **The LookTel** application, developed for the visually impaired, provides the opportunity to scan and instantly recognize related with money transactions. Users point their mobile phones at the bill and take a photo of it. They can hear the total amount. **SoundPrint** is a mobile application specifically developed for individuals with hearing impairments. This app helps users assess and share the noise levels in restaurants, bars, and other public venues. SoundPrint evaluates the noise levels at various locations, assists in finding quiet places, and facilitates the creation of community-based information by allowing users to share their assessments of venues with others. Another major problem faced by individuals who use wheelchairs is the suitability of the places they intend to visit for their own conditions. The **Wheelmap** application marks the accessibility of heavily frequented places for people with disabilities on the map. This way, individuals with disabilities can be informed in advance about the accessibility of the places they plan to visit. **Dragon Naturally Speaking** is a speech recognition software that uses speech to text, allowing users to dictate rather than type. It is an application that especially assists individuals with visual impairments in tasks like document preparation, email usage, and computer control. It allows users to communicate by speaking without the need for a keyboard or mouse, especially when creating text documents or using their computers. **Talkitt** is an application developed for individuals who have speech and language problems and cannot communicate with others. The application can learn the user's speech and language and translate accordingly. This app, which translates incomprehensible pronunciations into understandable speech, helps people with cerebral palsy, ALS and other speech disabilities. The project called **Facing Emotions** was developed with a new programming language. Thanks to this, the phone, which can be attached to the human body with an electronic device, converts facial expressions and emotions into sound with its rear camera using facial recognition technology and transmits it to the headset worn by the visually impaired person. With this application, which can analyze the voice according to the emotion people feel to the other party at that moment, it is a big step towards eliminating some of the obstacles that may arise for disabled individuals. **VizWiz, Orbit, SayText** are some of the many applications developed for disabled people.

## Virtual / Augmented / Mixed Reality Based Assistive Technology

VR is interactive simulations in which computer-created three-dimensional environments are experienced with more than one sense (Muscott & Gifford, 1994, p. 417). Since the 1990s, VR applications have been the subject of educational studies for special needs groups. In these years, researchers began to use virtual environments to teach people how to use wheelchairs (Inman et al., 1994). Individuals with special needs have limited access to the outside world. They can gain the experience of acquiring these skills in virtual environments, especially in situations where physical requirements are required (crossing the street, operating a stove or oven, cooking, etc.). Virtual environments also enable experiencing expensive, dangerous and difficult conditions (Kandalaft et al., 2013, p. 35; Novak, 2009, p. 28). VR technology provides permanent learning by giving users the feeling of being there in the user's brain with the virtual environment experience it provides and allowing it to be recorded as a memory experienced in the mind (Bailey et al., 2012, p. 24). VR technologies also create great opportunities for disabled people with the experience they provide.

Navigation and reading are two of the most significant challenges faced by individuals with visual impairments. Warning signs and location markers in both indoor and outdoor environments can pose difficulties for people with disabilities (Sezgin, 2020, p. 91). **Microsoft HoloLens,** is an intelligent mixed reality headset powered by AI and machine learning. Microsoft HoloLens offers a sign-reading application designed to provide a solution for individuals with visual impairments. The device utilizes cameras and audio sensors to obtain real-time information, processing it to relay the locations of surrounding individuals to the user's ear within second. At Aalto University in Finland, orientation for wheelchair-using students on campus is being conducted using **Oculus Rift VR** glasses. The integration of VR hardware into wheelchairs has been observed to accelerate the adaptation of disabled students to the school (Lawther, 2016). The VR simulator called **VADIA** assists young individuals with autism in developing independent behaviors and improving their driving skills for autistic individuals. **Eye Play the Piano** can be commanded by eye movements to the digital piano presented in the VR environment and enables the use of the piano for physically disabled individuals (Eye Play The Piano, 2023.)

**Figure 9.** *Hololens and Eye Play The Piano*

**DeepStream VR** is a company specialized in creating immersive virtual worlds to help alleviate pain. They offer compelling VR experiences that enhance the quality of life for patients. They utilize VR technology in various areas, including physical and cognitive rehabilitation, phobia treatment, improving social skills, stress reduction, meditation practices, and entertainment for individuals with disabilities. VR technology has opened up many possibilities to improve the lives of patients and individuals with different needs. Mixed reality creates a new environment by using both virtual and augmented realities. The key distinction between mixed reality and augmented reality is that in mixed reality, users can interact with virtual objects and data in real-time. **Microsoft Mesh**, a mixed reality platform, integrates with various devices such as smartphones, computers, tablets, VR headsets, and augmented reality glasses to offer users a holographic experience. This allows people to come together in virtual environments regardless of time and location. Microsoft Mesh provides users with various advantages, including the ability to work with 3D models in real-time and interact with other users by creating holograms or avatars (Papuççiyan, 2021).

## Challenges and Solutions of Assistive Technologies

Evidence presented by different organizations shows that people with disabilities experience discrimination and inclusion problems. ATs are considered as a medical condition that needs to be managed or treated for disability, to maintain and increase the individual's independence, to participate in society. However, in the last few years, some technological advances, defined as accessible technology, have addressed disability not only as a functional limitation but also as a barrier to social integration. In this respect, technology is seen as a factor to facilitate and normalize the lives of individuals with disabilities, especially in terms of reducing certain barriers in the field of employment (Kritikos, 2018, p. 4).

Today, AT undoubtedly serves important purposes for many disabled individuals. But unfortunately, it also faces many difficulties. We can list the difficulties such as accessibility, costs, designs, usage levels, countries' policies, and users not being aware of it or not knowing how to use it.

With the regulation made on 19 February 2014 in the Law on Disabled Persons, definitions regarding accessibility are also included. In article 3 of the law; "Accessibility; buildings, open spaces, transportation and information services, and information and communication technology should be accessible and usable by disabled people safely and independently". Accessibility refers to the fair and equal distribution of resources so that individuals have equal opportunities to access appropriate products and services for their needs. In order to access products and services, accessibility to information, transportation and communication is required (Kritikos, 2018). According to this concept, disabled people should be able to leave their homes without needing anyone else, go wherever they want, and use the products and services they want easily and without needing anyone else. Physical and architectural measures need to be taken and adapted to developing AT in order to ensure participation in city life. Making the necessary design arrangements at the accessibility level so that disabled individuals can continue their daily life activities such as living-resting-entertaining and shopping like healthy individuals, should be considered important in solving the restrictions of disabled individuals from social life. Public policies developed especially for disabled individuals and environmental accessibility need to be integrated with each other. The development and adaptation of institutional places such as markets, post offices, hospitals, cities, cinemas, roads, cars and all the things we need on a daily basis around us in accordance with the use cases of developing AT will become even more important in the future. AT should be adapted to the needs of disabled people and be easily accessible. Solutions that are only offered in certain regions contradict the principle of accessibility. Various elements, such as an individual's functional capacity, awareness level, socioeconomic standing, living circumstances, and engagement with their surroundings, play a role in determining their requirements for and availability of AT. Comprehensive comprehension of the associated needs within the populace and recognizing the primary obstacles to obtaining assistive products are crucial initial prerequisites for enhancing accessibility (WHO, 2022, p. 24).

Some AT is much more expensive than individuals can afford. Although some of them are suitable, individuals do not have the power to resist them. Purchasing the AT needs of disabled individuals may vary depending on the health policies of the countries. While some countries cover some of the ATs depending on the disability, some do not cover any of them. ATs must be obtained by individuals with disabilities, especially since they are not included in health insurance or other reimbursement mechanisms. And this is often quite expensive, making it impossible for everyone to use it. According to WHO (2018, p. 6), it is estimated that 1 million people in the world need AT. However, only 1 in 10 people can access AT products. It is estimated that this need will double in 2050 with the aging of the population and the increase in non-communicable diseases. In anticipation of the great need, WHA (World Health Assembly) called on member states and WHO to improve access to AT as part of universal health coverage. It is very important to define AT as a medical device or for general use. If the AT has a medical label, the social system can pay for the use of the disabled individual, whereas when the AT is defined for general needs, the user has to pay the cost (Kylberg et al., 2015, p. 63). This situation confronts disabled individuals with a great difficulty.

Data is needed to fully determine the AT need in a country. There may be errors in estimating the AT need due to lack of data or inadequate information systems in institutions or, more generally, in countries. Therefore, giving due importance to data entries is important in determining the need for AT. Countries face challenges in accurately predicting and meeting the AT needs of the population due to limited information systems. The lack of structured and harmonized data leads to incorrect assessments of AT supply and demands. Therefore, developing strategic action plans to accurately understand and improve a country's population's AT needs is critically important (Al-Tayar et al., 2019, 5-6).

Individuals with disabilities may lack awareness of what assistive technological products and services are or about accessing these services. Health centers, government institutions or non-governmental organizations to which disabled people are affiliated may lack the knowledge, skills and awareness to direct disabled people to appropriate service providers. According to WIPO (2021, p. 219) the number of personnel specifically trained in providing access to AT is low in many countries. Because there are many types of disabilities, users need to know which type of assistive product will help them the most and where they can access these products. It is necessary to provide ways to access this information in health centers and in environments accessible to everyone.

Some ATs have very complex features and can provide services in different languages. The availability of language variability in service-providing products in accordance with the nationality of the disabled individual will ensure clarity. In addition, although the language efficiency of the region used is ensured, the technical equipment and use of the products may be difficult for some disabled individuals. Therefore, it may be necessary to provide training to people who are competent in this field.

Today, technology is constantly developing and progressing. For example, one technology can change very quickly, while another technology can change completely differently than before. For example, ATs, especially those with high technology, that have old software may need new updates. Or old devices may not adapt to new environments. Therefore, both manufacturers and disabled individual users may need to constantly update the systems.

While some AT devices may be complex for the elderly, some may not adapt to the situations of disabled people. For this purpose, those who design AT products need to determine very well the target audience that will use the products. The "knowledge gap" between the design team and target users can cause design problems and lead to ATs not being used or developed adequately. In order to solve the problem of information gap, those who design or produce the product may need to exchange information with disabled people.

Abandonment of ATs by end users still continues to be a problem. Among the reasons why end users stop using these technological devices is their inability to meet AT designs and needs (Federici & Borsci, 2016, p. 22-23). This situation causes the benefits obtained from AT procurement to decrease (Tao et al., 2020, p. 1028). In order to cope with this challenge, end users should be informed in detail by authorized persons before purchasing AT products, and if necessary, they may even be given the right to use them for a certain period of time. The practical usefulness, ease of maintenance and environmental compatibility of the AT to be recommended to disabled individuals are important details for its adoption by the individual. Those who will use AT should first adopt the products or services, so that they reduce the possibility of abandoning these products in a short time.

According to WHO (2022, p. 53), in order to combat these existing challenges and ensure the development of AT and make it stronger, it is necessary to address policy, product, provision and personnel components. **Policies** funding, and programs to ensure universal access to ATs vary from country to country and require effective leadership and governance. ATs can be integrated into countries' health and social systems. An adequate and continuous source of funding can protect users from financial difficulties. This is only possible with the joint action of government institutions and insurance programs. **Products;** increasing the quantity, quality and diversity of products and making their prices affordable are important for AT. At this point, it may be necessary to develop various strategies. In order to reduce the cost of products, local manufacturing or imports can also be a solution. Investing in field at national and global levels, increasing the lifespan of products through repair and replacement, and creating efficient supply chains are among the improvements that can be made on products. **Provision;** it includes services including accessible information, user training and monitoring. Purchasing mechanisms can be used to increase the variety, quantity and quality of ancillary products and reduce costs; and information systems and the data generated can be used to help improve service delivery. **Personnel** who will provide the products (such as nurses, pharmacists, healthcare workers) can be developed to enable the development of assistive products. And it is important that these people are made aware or trained about ATs and that they are able to convey this information to the end user.

## Conclusion

In this study, examples of emerging AT for individuals with disabilities are provided, aiming to raise awareness about the advanced state of technological developments in this field. Just as there is diversity in disabilities, there is also considerable diversity in AT. In this study, only a part of it could be addressed. While ATs struggle to keep up with advancing technology, the study addresses challenges despite the high impact that advanced technological products and services can have on improving the lives of individuals with disabilities and also according to challenges encountered suggestions are presented to overcome these challenges.

Information technologies and the internet enable people today to find easier, faster, and more economical solutions to their information and communication needs. As a result, individuals with disabilities can participate in socio-cultural, educational, and economic life. AT are used to enhance or increase the independence of individuals with disabilities, facilitate their participation in the social environment, and indirectly increase employment and well-being. In addition to traditional AT, the development of advanced AT has increased with the rise of digitization. Particularly, the development of high-level AT, such as the IoT, sensor technology, AI, robotics, and virtual/augmented/mixed reality technologies, as well as mobile applications, can be observed in the design of assistive products and services for individuals with disabilities.

Sources indicate that the majority of people with disabilities encounter discrimination and face a series of obstacles that prevent them from exercising their rights. Although access to assistive devices and technology is considered the foundation of fundamental human rights such as respect, autonomy, equality, and participation (Kritikos, 2018, p. 4), individuals with disabilities may still face various challenges related to AT. Among the challenges of AT are difficulties in accessing products and services, lack of awareness, high costs, lack of education in usage, and deficiencies in the public regulations and procedures related to individuals with disabilities in countries. Considering the anticipated increase in the elderly population and according to WHO predictions, necessary regulations regarding AT challenges should be made by governments, product suppliers, and service providers. Challenges related to AT should be considered as part of sustainable development and prioritized by governments. AT undoubtedly revolutionize the lives of individuals with disabilities. However, it should be remembered that technology alone has limited efficacy for the continuity of life. To fully enrich the lives of individuals with disabilities, social and legal barriers must be eliminated, emphasizing that the "human" factor is as important as technology in this process.

The rapid advancement of information technology and the easy adaptation of the products and services we use are crucial in facilitating the use of AT for individuals with disabilities, enhancing their comfort in life, and promoting their social integration. In this sense, AT can reduce this inequality by enabling individuals with disabilities to be productive and participate in all aspects of life. AT can have a significant impact on empowering young people, allowing them to participate effectively in education and employment. Therefore, governments should prioritize them as a fundamental component of inclusive sustainable development.

The infrastructure necessary for delivering efficient AT services is an intricate concept that mirrors the intricacy of individuals' lives and requirements. It is imperative to tackle this comprehensively, acknowledging that AT serves as a fundamental avenue for accessing human rights, continually adapting to meet evolving needs.

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CHAPTER

# Research on Current Sectoral Uses of Motion Capture (MoCap) Systems

2

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## Introduction

The Oxford English Dictionary defines movement as a process or the act of acting; from this point of view, *movement* means *the act or process of moving, change of location, position or posture, or transition*. The key concept for activity, the transition from one place or state to another, is *change* since change is always achieved only by transitioning from one state to another (Ng, 2012). According to the Turkish Language Association Dictionary, Animation was derived from the French term *Animation* and passed into Turkish as "Animation" (T.D.K., 2023).

Today, it is clear that the swift progress of technology generates innovation and advancements in various fields. Since the inception of the pioneer fully animated cartoon by Émile Cohl in 1908, animation approaches have vastly progressed from 2D monochrome visuals to incredibly realistic 3D representations, thus enabling the production of movies that are occasionally indistinguishable from live-action films. Computer animation was previously used to a limited degree in movies like '*Star Wars*', '*Tron*' and 1978 '*Superman*'. However, the release of '*Terminator 2*' in 1992 and '*Jurassic Park*' in 1993 introduced a highly advanced image processing technique. Despite only using 14 minutes of visual effects for the dinosaurs, '*Jurassic Park*' made a lasting impression on its audience. The animation process in contemporary cinema has evolved into a complex and intricate structure marked by metamorphosis since its beginning. Animation artists face an arduous task in navigating this complicated process. Over time, various methods and multidisciplinary investigations have been undertaken to address the challenges and shortcomings (Arslan & Taş, 2019).

Motion capture, or MoCap for short, is the process of recording the movements of people, animals, or plants and transferring them to a digital environment. This technology is used to create more realistic 3D models through computers, and thanks to sensors placed on the body of a live actor, the movements made are converted into a digital environment in X, Y, and Z coordinates. This digital data is then synchronized with computer-generated 3D models to create animations that mimic live movements (Akören, 2018).

Motion capture and computer animation techniques have significantly advanced in the gaming and film industry. However, today, the perception of human movements in 3D and their representation in a 3D virtual stage is still a research problem. There are generally two ways to capture motion: *marker-based* and *markerless motion capture* techniques. While there are many disadvantages to marker-based motion tracking, the most significant drawback is that the player wears an outfit of sensors or markers, and the process involves using multiple cameras placed in a room. For this reason, markerless motion capture has become a more prominent area of research. In unmarked motion capture, the player does not have to wear some sensor suit, but still, unmarked motion capture is a challenging task (Shingade & Ghotkar, 2014).

Motion tracking is fundamental in developing intelligent autonomous robots. Through sensing, robots can interact, cooperate, or imitate human movements. In recent years, tracking technology has become more accessible and compact. Advanced algorithms for tracking and post-processing techniques are used to reduce measurement errors. Various sensing mechanisms enable many applications in autonomous systems, with different sensors recording and measuring precise positions and movement directions. Sensing methods *encompass magnetic fields, accelerometers, gyroscopes, ultrasonic pulses, and cameras*. These modalities enable motion tracking and measurement of the robot's orientation, a vital feature for autonomous robots as it allows for human-robot interaction (M. Field et al., 2009).

This section will provide an overview of how motion capture technology works and how it is used today in different industries such as *cinema, entertainment, healthcare, sports, arts, education, and industry*.

## Purpose and Problem of the Research

Although animation, obtained by playing inanimate pictures serially at a certain speed, has become more accessible thanks to the development of computer technologies, much work still needs to be done to reflect the animations realistically. This research aims to make a compilation of *Motion Capture Devices and Techniques*, which are used as a source of motion for animations and have many other uses, to explain their application areas with examples and make predictions about their future use.

## Research Questions

The questions of the research were determined as follows:

- What is a motion capture devices and systems?
- In which industries are motion capture systems used?
- What are the uses of motion capture systems on a sectoral basis?
- What might motion capture systems be used in the future?

## 1. Motion Capture Systems

Motion capture is a process that can capture and determine the position of points fixed to an actor's body at a specified time interval with a piece of equipment. As a motion capture system, these operations can be performed with optical, inertial, mechanical, magnetic, or acoustic sensors. The methods used in **Table 1** and the advantages and weaknesses of these methods are given **(**M. Field et al., 2009**)**.

**Table 1**. *Comparison of Advantages and Disadvantages of Motion Capture Techniques (M. Field et al., 2009)*

| Method | Advantages | Disadvantages |
|---|---|---|
| ***Optical-Based-Passive*** | Accuracy < 1 mm<br>Wireless<br>Less load | Location only<br>Limited measuring space<br>Optical closures<br>Post-processing delay |
| ***Optical-Based-Active*** | Accuracy < 1 mm<br>Wireless<br>Higher range than passive | Location only<br>Limited measuring space<br>Optical closures<br>Post-processing delay<br>Fs split between sensors<br>The load of cables in the body |
| ***Optical-Based - Markerless*** | Wireless-Outdoor<br>Resilient<br>No sensor load<br>Contextual information | High noise<br>Optical closures<br>High cost of post-processing<br>It is usually not real-time<br>High sensitivity to lighting |
| ***Momentum Based*** | Accelerations<br>A degree of precision <<br>Wireless - outdoor<br>Quick calibration<br>Portable | Reference positions yok<br>Post-procedure - external contacts<br>Noise<br>Magnetic perturbations |
| ***Mechanical Based*** | Portable<br>Wireless-outdoor<br>Rugged, reliable | Restrictive movement<br>No reference location<br>Relative orientation only |
| ***Magnetic Base*** | Portable<br>Wireless-outdoor<br>Flexible sensor arrangement | Limited range<br>No reference location<br>Magnetic perturbations |
| ***Acoustic Based*** | Portable<br>Wireless-outdoor<br>Flexible sensor arrangement | Partial occlusions<br>No reference location<br>Environmental conditions |

Usually, the apparatus the actor must wear takes place using an outfit or similar tool. Effectively, the points around the actor's body can move passively or actively in capturing and recording. In this set, selected markers are connected to the reading system by a series of cameras pre-prepared for this function or through cables. This data is reviewed by scanning reference points on the actors' bodies, digitizing their movements, and mapping the activities as a digital model. Unlike traditional methods, frame-by-frame rendering is done with motion capture (Tiago, 2016).

The technologies used in motion capture systems have some clear and challenging issues that must be overcome. Some of these are given below (S. Sharma et al., 2019):

***Inconsistency of limited formats:*** Sometimes, creating differences between the actor and the animated object is more challenging. For example, a digital character is much larger than the actor's body, creating problems such as object overlapping. Therefore, much correction is required. In this case, it is a time-consuming process for the animator, and sometimes, it becomes impossible to use motion capture for this type of animation. ***Real-time visualization:*** To date, only some systems allow realistic scenarios to be visualized. Most of the time, it is necessary to start remaking a specific video sequence, which is more accessible than editing the data. ***Movement and space constraints:*** In these systems, there is an obligation to follow physical movements in the first place. Then comes the restriction of processing in a limited area. Problems like finite and magnetic field interference vary according to moving or stationary positions. ***Equipment and its associated costs:*** Some equipment, including motion in the video stream, is needed to capture some software, including the cost of operation, and they pose the problem of maintenance cost, which is a challenging issue for small businesses. ***Need for editing:*** Motion captured from the video stream requires editing because the original data tends to be constrained, and eventually, edits are imperative (S. Sharma et al., 2019).

## 1.1. Motion Capture Methods

Motion capture methods have been grouped as follows (S. Sharma et al., 2019);

- **Marker-Based Motion Capture Systems**
  - ***Acoustic systems:*** This method is based on the vocal transmitters, the actor's main joints, and three receptors. The emitters are then activated and generate a range of frequencies while the receivers detect the position accordingly. The reflection of sound can make the process difficult to detect (S. Sharma et al., 2019).
  - ***Mechanical systems:*** In this method, potentiometer sensors placed on the joint areas of the actor are used. They are calculated in positions while producing different resistance values according to the movement. It can give more accurate output because it is not magnetically affected (S. Sharma et al., 2019).
  - ***Magnetic systems:*** In this method, movements are detected according to the change of magnetic fields in the direction of the joints. Metal areas tend to be affected (S. Sharma et al., 2019).
  - ***Optical systems:*** There are light-reflecting elements on the actor. The position of the movement is calculated according to the state of their images. Sometimes, problems include the inability to display reflectors (S. Sharma et al., 2019).

- **Markerless Motion Capture Systems**
  - In this method, movements are tried to be detected using image processing over a video. No sensor equipment is used; it is software-based. An example is given in Figure 1 (S. Sharma et al., 2019).

**Figure 1.** *Markerless Motion Capture (S. Sharma et al., 2019)*

Motion capture technology has been in development since the 70s. Since then, many ways to use this technology have been created. The main motion capture methods can be divided into three: optical, mechanical, and electromagnetic-based motion capture (Tiago, 2016).

### *1.1.1. Optical-based motion capture method:*

In the optical-based motion capture technology, known as passive marking, an actor dons an outfit studded with markers. A network of cameras captures images of these markers, which are then processed by software to digitally replicate the movements by creating triangulation points. These markers come in small reflective spheres or infrared signal emitters. One advantage of this system is that it enables actors to move freely without cables or connections. The tool captures the actors' movements and data more precisely and clearly than other methods. However, lighting conditions may adversely affect capturing footage, a drawback of this recording format. Reflexive points may become obstructed by the actor or by surrounding objects, leading to data loss. This hinders the estimation and recalculation of position for already missing points. Additionally, scanning is essential before data can be viewed. Due to the complexity of captured motion, the resulting motion animation can take considerable time and hinder progress. Figure 2 depicts an example of optical-based motion capture equipment (Tiago, 2016).

**Figure 2.** *Example of Optical-Based Motion Capture Equipment (Tiago, 2016)*

### *1.1.2. Mechanically based motion capture method:*

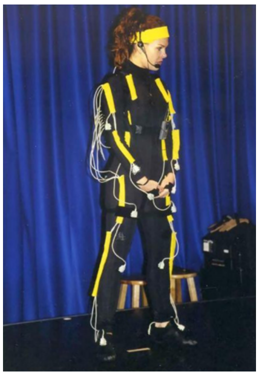
In this approach, the performer dons a suit fitted with sensors, like an exoskeleton. As the performer moves, the sensor system tracks their movements, which are recorded and digitized. Additional mechanical captures comprise gloves, robotic arms, and articulated models crucial for framing (key points guiding animators in their work). One limitation of this method is that the suit is insensitive to magnetic or light interactions. However, there are drawbacks, such as the lack of grounding sense causing jumps during actor interpretation. Moreover, the equipment requires frequent recalibration as it cannot recognize its absolute position. Figure 3 is displaying mechanical motion capture equipment (Tiago, 2016).

**Figure 3.** *Examples of Mechanical Motion Capture Equipment (Tiago, 2016)*

### *1.1.3. Electromagnetic-based motion capture method:*

The system utilizes receivers embedded in the actor's joints, which operate through a sequence of magnetic reconfigurations. These receivers ascertain the position of points on the actor in space through magnetic calculation and transmit a signal to the receiver linked to an antenna. Notably, this system produces real-time responses, provides instantaneous motion capture, has a low computational cost, and is low-cost in equipment. The primary drawback of this equipment is the possibility of magnetic distortion, as concrete floors may contain metal and interfere with detection. A stage suitable for magnetic insensitivity must, therefore, be constructed. Another issue is the multiple cables, which must be connected to an antenna and run through the actor's body. Figure 4 depicts an instance of magnetic-based motion capture equipment (Tiago, 2016).

**Figure 4.** *Example of Magnetic Motion Capture Equipment (Tiago, 2016)*



## 2. Sectors Where Motion Capture Technologies Are Used

Motion capture systems are widely used in today's realistic films and provide an opportunity for use in sports, entertainment, video games, and much more (S. Sharma et al., 2019).

Although the use of motion capture technology is standard in cinema and television productions, it is a fact that it makes itself felt strongly in many different business lines, such as medicine, defense, sports, entertainment, games, and art. For example, motion capture technology can provide great convenience in producing on-site and practical solutions for the measurement and evaluation of athletes' physical performances in sports (Kozan, 2022). Figure 5 provides some examples of the use of motion capture technologies.

**Figure 5.** *Examples of Usage Areas of Motion Capture Devices (Özkirişçi, 2022)*

## 2.1. Cinema And Television Sector

While the digital transformation in cinema has changed many application processes used in filmmaking, it has revealed the existence of a cinema-technology relationship that is more dependent on technology. As a reflection of this relationship, the increasing use of motion capture technology in films is remarkable. The most substantial evidence of this situation is that a significant part of the production of motion pictures such as *Avengers: Endgame* (2019), *Avatar* (2009), *Titanic* (1997), *Star Wars: The Force Awakens* (2015), *Avengers: Infinity Wa*r (2018), and *Jurassic World* (2015), which are the most watched in the world, was carried out by using motion capture technology (Kozan, 2022).

When the IMDb site is scanned with the words *Motion Capture*, 219 productions using this technique are listed. When these productions are ranked according to popularity, the shows are in the top 25 of the list, and their IMDb scores are seen in **Table 2** (IMDb, 2023).

**Table 2.** *Top 25 Most Popular Using Motion Capture Techniques in the IMDb Productions (IMDb, 2023)*

| Production Name | Year of construction | IMDb Rating |
|---|---|---|
| 1. The Little Mermaid (I) | 2023 | 7,2 |
| 2. Guardians of the Galaxy III | 2023 | 7,9 |
| 3. Titanic | 1997 | 7,9 |
| 4. The Lord of the Rings: The Fellowship of the Ring | 2001 | 8,8 |
| 5. Avatar: The Way of Water | 2022 | 7,6 |
| 6. The Avengers: The Endgame | 2019 | 8,4 |
| 7. The Lord of the Rings: The Return of the King | 2003 | 9 |
| 8. Monster House | 2006 | 6,6 |
| 9. Thor: Love and Thunder | 2022 | 6,2 |
| 10. Guardians of the Galaxy | 2014 | 8 |
| 11. Alice in Wonderland (I) | 2010 | 6,4 |
| 12. Star Wars: Chapter I - The Hidden Danger | 1999 | 6,5 |
| 13. Beauty and the Beast (I) | 2017 | 7,1 |
| 14. Avatar | 2009 | 7,9 |
| 15. The Lord of the Rings: The Two Towers | 2002 | 8,8 |
| 16. Start | 2018 | 7,4 |
| 17. Hobbit: Unexpected Journey | 2012 | 7,8 |
| 18. Thor: Ragnarok | 2017 | 7,9 |
| 19. The Amazing Spider-Man | 2012 | 6,9 |
| 20. Star Wars: Chapter III - Revenge of the Sith | 2005 | 7,6 |
| 21. The Amazing Spider-Man II | 2014 | 6,6 |
| 22. The Lion King | 2019 | 6,8 |
| 23. Alaaddin | 2019 | 6,9 |
| 24. Malefiz | 2014 | 6,9 |
| 25. Star Wars: Episode II - Attack of the Clones | 2002 | 6,6 |

Impressive examples of motion capture technology in the motion picture industry include big-budget productions such as *The Lord of the Rings* franchise, *Avatar*, *Planet of the Apes,* and *Avengers*. These films are examples of the creative potential of motion capture technology in the motion picture industry. Motion capture technology allows the cinema industry to create realistic characters, believable special effects, and dramatic scenes. This technology has become indispensable for making movies more immersive and providing audiences with unforgettable experiences. From the mid-to-late 80s and early 90s, the technology was developed and applied more often in entertainment projects, widely used in real-time animation for television - in 1991, a French producer called Medialab developed the character *Ghost Mat*, which aired with one-minute appearances every day for more than three years for a T.V. show. In the same year, the movie *Terminator II* was released, and this technique was used to portray the character of the *T-1000*, a robot made of liquid metal (Tiago, 2016). Figure 6 shows examples of the use of an optical-based motion capture system in famous cinema productions.

**Figure 6.** *Use of an Optical-Based Motion Capture System in Cinema (Tiago, 2016)*

Motion capture methods may find their use in the cinema and T.V. industry in the following ways:

### *2.1.1. Creation of Digital Characters*

During the mid-to-late 1980s and early 1990s, this technique was developed and utilized increasingly in entertainment projects, particularly in real-time television animation. In 1991, Medialab, a French producer, created *Ghost Mat*, a character featured in a television program in one-minute daily footage for over three years. *Terminator II* was released the same year, using this technique to depict the character *T-1000*, a liquid metal robot. Although motion capture had been used before, film first applied the technique to a related character. Cinema remains one of the largest industries using this technique today, and video games also play a significant role. In the 1990s, video games were responsible for most motion capture use in animation and continue to be used for entertainment. Motion capture technology is widely used in technically and artistically superior games. Digital game consoles, including *Nintendo Wii, Xbox, and Playstation EyeToy*, also utilize it to transfer players' movements into games (Tiago, 2016).

Motion capture techniques were used to portray the T-1000 liquid metal body, one of the characters of the *Terminator II* movie. This character is designed to take various forms in movie scenes, disintegrate, pass through irons, and turn his hand and body into weapons. Figure 7 shows an image of this character (Wikipedia, 2023).

**Figure 7.** *T-1000 Character Used in The Terminator 2 Movie (Wikipedia, 2023)*

### *2.1.2. Improving Actor Performances*

Motion capture is also used to make actors' performances more believable. Especially in fantasy and science fiction films, motion capture allows actors to express their emotions and movements on digital characters. This gives movie viewers a more immersive and realistic experience. MARVEL Studios, one of the leading studios, also uses motion capture techniques. Motion capture is used to animate various characters, such as the Hulk. The actor's movement is recorded, and the recorded data is then pasted onto the character model. This way, the animated Hulk character is given direction (S. Sharma et al., 2019). Figure 8 shows an example of a scene from a digital character played by Tom Hanks.

**Figure 8.** *A Scene from The Movie The Polar Express (Özkirişçi, 2022)*


### *2.1.3. Enhancing Physical Interactions*

Motion capture technology accurately captures characters' physical interactions. It can portray fight scenes, collisions, and object interactions with greater naturalness and fluidity. Sensors are attached to various points on the actor's body to capture their movements, while high-resolution digital cameras track the sensors' displacement and transmit this information to a computer. The information can be utilized to animate a CGI (Computer Generated Imagery) figure, which on-screen designers and animators produce. This technique was applied when depicting the protagonist in the 2005 film King Kong and for Gollum, Caesar, and Captain Haddock in Steven Spielberg's The Adventures of Tintin. The fusion of motion capture data from an actor's performance, and CGI enables the screen to feature supernatural beings, digital stunts, or extensive groups of personnel that appear like actors. For instance, in Val Kilmer's Batman Forever, several of his actions were executed by a computer-generated stuntman. Furthermore, the spectators in Ridley Scott's Gladiator were produced through motion capture data from two thousand human participants (Auslander, 2017).

*The Lord of the Rings: The Fellowship of the Ring* (2001), directed by director *Peter Jackson*, is seen as a turning point in the history of cinema in terms of virtual characters in the history of cinema with the character of *Gollum*, his movement performance, and his convincingly realistic appearance. Film critics see the character of *Gollum* in the *Lord of the Rings* trilogy as worth watching. The movements of the character of *Gollum* were created by adapting the acting performance of the famous actor *Andy Sarkins* to the character of *Gollum* with motion capture technology (Çalışkan, 2021). Figure 9 shows actor *Andy Sarkins* portraying the character of *Gollum*.

**Figure 9.** *Andy Sarkins Portraying the Character of Gollum (Letteri, 2013)*

### *2.1.4. Stunt Coordination and Safety*

Stuntmen can take part in dangerous movements and action-packed scenes. Motion capture technology can be used to ensure the safety of stunt performers and actors. Complex settings can be planned and simulated to minimize risks during shooting. In this context, XSens' motion capture devices were used in the movie *Black Panther*, one of the closest examples today (Xsens Stunt, 2023). Figure 10 shows the image of the news about the use of Xsens devices by the *Black Panther* movie stunt performers.

**Figure 10.** *Black Panther Movie Stuntmen's Use of Xsens Motion Capture Devices (Xsens Stunt, 2023)*


## 2.2. Digital Game Sector

Motion capture technology is utilized across numerous aspects of the video game industry, encompassing character animations, player performances, emotional expression, and motion controls. This innovation enhances the gaming experience, rendering it more immersive, realistic, and personalized while equipping game developers with increased opportunities for creativity and innovation. Motion capture techniques play a significant role in video games. During the 1990s, this medium was primarily responsible for the widespread use of motion capture technology in animation. It continues to be used for entertainment, particularly in technically and artistically advanced video games. These games, available on consoles including *Nintendo Wii, Xbox, and Playstation EyeToy*, incorporate players' movements through motion capture (Tiago, 2016).

Motion capture methods can find a use in the digital game industry in the following ways:

### *2.2.1. Character Animations*

In video games, motion capture technology allows character animations to be more realistic and fluid. Players' movements in the real world are directly transferred to the digital game characters. In this way, the characters move more human-like and naturally. Motion capture technology has been followed with interest by the largest companies in the video game industry, such as *Electronics Arts (E.A.)*. It has established motion capture studios in Vancouver, Canada's world's largest studios. *Electronics Arts (E.A.)* agreed with famous sports teams and players of the time for game consuls about important football and basketball matches such as *FIFA WorldCup*, *Madden N.F.L.*, and *N.B.A. Live*. They took electronic recordings by wearing motion capture suits. These recordings were then converted into ready-made patterns suitable for the movement commands of virtual players in the game consuls (Kozan, 2022).

*Electronics Arts (E.A.)* is working to make *FIFA 23* the most expansive and realistic game in the series. To achieve this, *Electronics Arts (E.A.)* has upgraded its motion capture system to *HyperMotion 2* and improved its machine learning algorithm. These tools capture and aggregate data from real football matches filmed by the team in *Zaragoza*, *Spain*, using Xsens technology, which allows for a more realistic virtual football experience. This entry in the series is visually authentic. Figure 11 offers a snapshot of the new game version that appears quite humanoid (Playstation Blog, 2023).

**Figure 11.** *A Still From The Fifa 2023 Game (Playstation Blog, 2023)*


### *2.2.2. Emotional Expressions and Gestures*

Motion capture technology reflects game characters' emotional expressions and gestures more believably. Players' facial expressions and body language are transferred to digital characters with motion capture, making emotional experiences in the game world more immersive (Kozan, 2022).

Motion capture technology, frequently used in cinema, first appeared in front of the actors in 1994. Japanese video game designer *Yu Suzuki* used motion capture techniques in *Virtua Fighter II* with *SEGA*. The game, where melee combat was at the forefront, offered more realistic animations than its period (ShiftDelete.net, 2023). Figure 12 shows an example of a game character animation.

**Figure 12.** *Game Character Animation with Motion Capture (ShiftDelete.net, 2023)*

*The MetaHuman Creator* software developed by *Unreal Engine* allows very human-like digital models to be designed. Moreover, these digital models can be paired with motion capture equipment to achieve humanoid movements. Figure 13 shows an example of a design made with *MetaHuman Creator Software* (MetaHuman, 2023).

**Figure 13.** *Realistic Digital Character Creation with Metahuman Creator (Metahuman, 2023)*


## 2.3. Health Sector

Motion capture processes are widely used in healthcare, particularly for biomechanical analysis. This analysis can help assess the requirements of a person needing a prosthesis. Motion capture can be used to analyze a person's movements and the areas where they apply more force, allowing for the identification of the body parts where the workload occurs. This data is then used to construct individualized prostheses and provide insights into the progress of rehabilitation work (Tiago, 2016).

Motion capture technology can be used effectively in the health and entertainment sectors. In this context, some usage areas are listed below:

### *2.3.1. Rehabilitation and Physiotherapy*

Motion capture technology is essential in post-injury rehabilitation and physiotherapy processes. Motion capture sensors make accurate analysis of patients' muscle and joint movements possible. By doing so, physiotherapists can recognize patients' weaknesses and movement disorders, allowing them to design tailor-made exercise programs. Measurements were taken in a study of 3D kinematic shoulder evaluation in patients with shoulder musculoskeletal disorders, focusing on highlighting clinically significant findings. Optical Motion Capture systems (O.M.C.s) are effective in orthopedic clinical practice, particularly for complex joint motion analyses like the shoulder. This technology enables accurate study of joint kinematics and collection of quantitative data. Careful assessment of postoperative joint movement can help evaluate surgical outcomes and customize patient care, improving postoperative recovery. Additionally, O.M.C.s can assess the efficacy of an ongoing rehabilitation protocol (Longo et al., 2022).

### *2.3.2. Evaluation and Treatment of Movement Disorders*

Motion capture technology is utilized to diagnose and treat various motion disorders. It objectively assists in evaluating medical conditions such as muscle and *joint diseases, neurological disorders, and posture disorders*. This technology enables healthcare professionals to analyze patient movements in real-time and utilize the collected data to determine the most effective treatment methods. The data collection involved 50 studies, ensuring a comprehensive examination of the subject matter. The single-use camera pointerless motion capture technology shows promise for identifying neurological injuries in *children and adults and hereditary/genetic neuromuscular disorders, fragility, and orthopedic or musculoskeletal groups*. Single-camera markerless systems perform well in studies involving single-plane measurements, such as gait analysis. However, 3D marker-based systems and various clinical outcome measures may be more effective when evaluating general infant movements or spatiotemporal parameters of gait. Nevertheless, they were inferior to marker-based systems in studies requiring meticulous monitoring, such as delicate movements like 3D kinematics or finger tracking (Scott et al.,2022).

Diseases that damage *muscles* and the *nervous system* can severely impair individuals' quality of life. *Hemiplegia, or partial paralysis*, is a condition that impacts both sides of the body and is caused by problems with the nervous system. This damage, which occurs in the brain, leads to mobility difficulties or inability to move. Effective treatment and rehabilitation are crucial stages of this disease. Early diagnosis is critical to initiating the rehabilitation process promptly. Technical terms are defined throughout. The primary objective of treatment is to facilitate recovery without causing any harm to other bodily functions. Consistent spelling, grammar, and footnote formatting are employed. The language is objective without being biased or vague. The study involved developing a game-based virtual reality application to detect patients' movements during rehabilitation. To accomplish this, twenty-three sensors were installed, including ten flexibility sensors on the patient's fingers and thirteen MPU9250 tilt sensors on the joints. The sensor data is primarily calibrated. Real-time sensor data is used to detect the movements of hemiplegic patients through virtual reality glasses. The game mode is created based on instructions given to patients by expert physiotherapists. Patients can play games according to the game mode while wearing virtual reality glasses. The physiotherapists' prescribed movements determine the game presented in this study. This game is believed to significantly contribute to the recovery process of patients with hemiplegia (Alakuş et al., 2021).

### *2.3.3. Surgical Simulation and Training*

Motion capture technology is employed in surgical training to simulate and practice accurate surgical procedures, enhancing surgical skills and speeding up learning. Motion capture technology is employed in surgical training to simulate and practice accurate surgical procedures, enhancing surgical skills and speeding up learning. This can help identify improvement areas and improve surgical skills effectively. Optical motion capture systems can detect differences in posture patterns, positional relationships between the elbow and wrist, and joint angles of the upper limb while performing robotic simulator tasks among groups of surgeons with varying levels of expertise (Takayasu, 2017).

The arrangement of facial muscles differs among males, females, and even individuals of the same gender. To elucidate the distinct expressions humans can exhibit, it is crucial to delineate the shapes of the muscles, their correlation with the skin, and their respective functions. Three-dimensional (3D) motion capture analysis, commonly utilized to examine facial expression, was employed to identify typical skin movements in both men and women as they performed six basic facial expressions in a single study. The movements of 44 anatomical marker points were measured using *Reflective Material (R.M.)* reflective markers. The displacement range exhibits large values in males, between 14.31 mm (fear) and 41.15 mm (anger). On the other hand, the displacement range is 3.35–4.76 mm, smaller in females, between 9.55 mm (fear) and 37.80 mm (anger). For males and females, 47.6% and 61.9% of R.M.s are part of the top ten maximum displacement values when forming at least one expression. The mean displacements caused by facial expressions are significant in both men and women. In terms of gender differences, men exhibit more significant R.M. movements compared to women, but their movements are more limited. To broaden our comprehension of facial expressions, we must undertake morphological studies of the facial muscles and related complex functionality. Utilizing quantitative analyses, as detailed in this study, will offer indispensable data for medicine, dentistry, and engineering. This information can prove advantageous for surgical operations relating to facial regions, software that predicts facial features and expression changes following corrective surgery, and for creating face-mimicking robots (Lee et al., 2015).

### *2.3.4. Supporting People with Disabilities*

Motion capture technology can increase the mobility of people with disabilities and facilitate daily living activities. Thanks to customized movement analysis and exercise programs, the quality of life of people with disabilities can be increased. The straightening movement was examined to design a mobility support vehicle for disabled people. Kinematic data were recorded through the image capture system developed for the physically disabled, and image processing methods obtained the markers fixed to the body and joint coordinates. Based on the Cartesian coordinate information describing the movements, the angular positions of the joints were obtained. Kinematic data were used in static force and power analysis. The results obtained from this study point to the feasibility of the planned mobility support system and form a basis for its preliminary design (Doğan et al., 2012). Figure 14 shows the capture of the straightening movement within the scope of the study.

**Figure 14.** *Digitization Of Straightening Motion With Motion Capture (Doğan et al., 2012)*

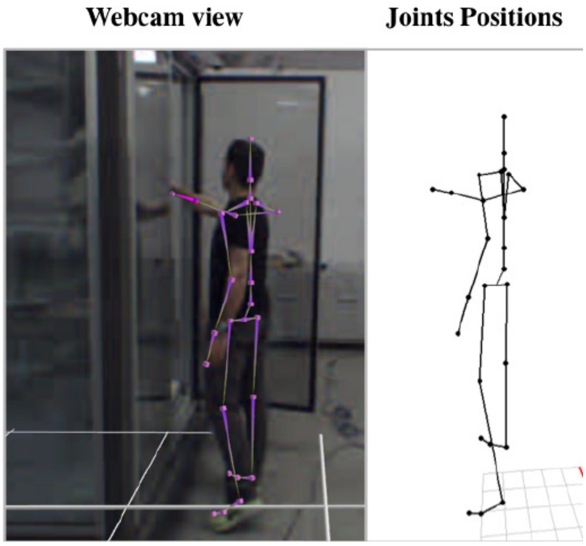
In a separate investigation, the researchers created an electronic system capable of detecting an individual's head movements to operate a prototype that predicts trends in wheelchair use. The design of the controller collects data on head movements through a motion capture system based on *MEMS sensors*. The study is divided into four phases. Firstly, the system was instrumented using a combination of hardware and software. Secondly, mathematical modeling was executed utilizing the principle of dynamical systems. Thirdly, automatic control of position, speed, and orientation was achieved through both fixed and variable rates. Finally, the system was validated via an electronic controller test protocol and user experience. A graphical interface was included to allow users to interact with all controllers in real-time. A score of 78 out of 100 was achieved via the *System Usability Scale (SUS)* after ten users assessed the system, indicating an ***excellent*** usability rating. The users suggested the implementation of laser sensors to enhance obstacle detection and improve safety instead of ultrasonic rangefinder modules (Callejas-Cuervo et al., 2021).

The *Internet of Things (IoT)* has brought about a change in every field and makes one's life easier with innovative and intelligent devices. Technology can also pave the way for disadvantaged people to do whatever they want to do, like their peers, by eliminating their disability and empowering them. Constantly monitoring a physically disabled baby can be a challenging process. For this reason, the project goal of the study was to establish an intelligent monitoring system for the baby's activities. The project's core is an ESP32 microcontroller, on which different control systems are located and sensors are incorporated. Of the included sensors, APDS9960 recognition was used for movement (whether there is any movement in the baby and whether the baby is asleep or awake), and MPU6050 Multi-Axis Accelerometer (protecting the baby from falling) was used for fall detection. As a result, it has been seen that the project can be effectively used for the care of physically disabled babies by their parents. In the future, cameras can be added to the system for more effective control (Ram Kumar et al.,2023).

### *2.3.5. Ergonomics and Occupational Health*

Motion capture technology is also used in the field of ergonomics and occupational health in the workplace. By analyzing workers' body movements and positions, potential hazards can be identified, and workplace designs can be improved. One study addresses a case study in the context of virtual ergonomics, specifically about the commercial refrigeration sector. The study aims to develop a computer-aided platform to analyze the postures of end-users and to ergonomically verify their movements and device design from the perspective of a man or woman. This paper explored the integrated use of human modeling and motion capture (MoCap) systems to perform ergonomic analysis precisely on natural movements. A case study of vertical refrigerator display units was conducted with the image-based motion capture mechanism installed, and results were obtained regarding ergonomics. An image from the application is given in Figure 15 (Colombo et al., 2013).

**Figure 15.** *Study to Examine the Postures of Individuals in Refrigerator Use from an Ergonomic Perspective (Colombo et al., 2013)*




### *2.3.6. Parkinson's and Neurological Diseases*

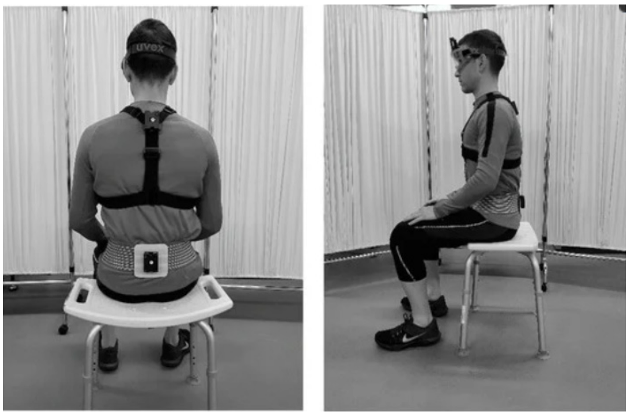
Motion capture technology can be used in the treatment of neurological diseases. In particular, movement disorders and imbalances of Parkinson patients can be evaluated so that more effective rehabilitation methods can be developed. In the study conducted by Fidan and Neşe (2018), a virtual reality-based disease tracking system is proposed for rehabilitating neural diseases such as *Parkinson, Cerebral Palsy, and Hemiplegia*. The study used a Kinect sensor to determine the patient's position (Fidan & Neşe, 2018).

*Single Camera Motion Capture (SCMoCap)* helps personalize feedback from motion analysis in situations such as the home rehabilitation of Parkinson's patients. A detailed 3D kinematic or marker-based approach is essential when the level of detail is low. Measured movements are often associated with identifiable events or are possible in situations indicative of Parkinson disease states. Studies in neurologically damaged infants have shown promising results. However, most studies have small sample sizes, and measurement errors have not been adequately reported. It is also unclear how measurement error affects clinical decision-making. The SCMoCap could be a valuable tool for movement disorders by enabling motion capture in the patient's home. However, further research should focus on improving tracking accuracy (Scoot et al., 2022).

### *2.3.7. Analytics & Research*

Motion capture technology in healthcare research provides essential patient movement patterns and behavior data. This data contributes to a better understanding of diseases and treatment modalities. In one case study, a study was conducted on detecting neck pain using machine learning techniques in healthcare. The aim is to objectify the diagnosis by automatic prediction of *cervical pain* and help clarify problems in insurance cases. An actual patient dataset of 151 patients (60 asymptomatic, 42 with cervical pain due to traffic accidents, and 49 with neck discomfort due to other causes) was used for the study. Cervical motion assessment tests were performed using a motion capture system. Combining machine learning and motion capture technology can provide objective tests to assist physicians. These tests can contribute to decision-making in diagnosis and treatment or help prevent discomfort for cooperative subjects. The established system is shown in Figure 16 (De la Torre et al., 2020).

**Figure 16.** *Cervical Motion Capture System (De la Torre et al., 2020)*



## 2.4. Sports Sector

Motion capture can be used to analyze the performance of athletes by providing information about how people move. It allows them to improve their performance by identifying their weaknesses. Capture works by analyzing a specific athlete in a specific situation and, more generally, by analyzing the performance data of all athletes involved in a match (Tiago, 2016).

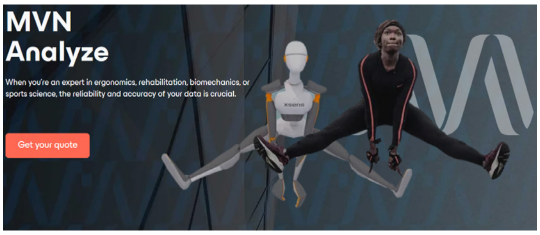
Many researchers are researching the applications of information technology, motion capture technologies, and 3D modeling technology to improve sports performance and facilitate training. The development of modern technology has dramatically influenced a particular sport's activity. It has been claimed that motion capture is used in the field of sports performance to track and record human movements in real-time to evaluate factors such as athletes' physical condition, technical expertise, athletic performance, and injury mechanisms, as well as prevention and recovery strategies (Talha, 2022).

Motion capture techniques are widely used for quantitative purposes in various sports disciplines and activity evaluation fields such as sports technique and competition. Also, from a biomechanical point of view, motion capture is the primary source of data that assists researchers in understanding movements to learn about the mechanics that govern the human being. In new approaches, the inertial sensor, added to newer technologies based on optical motion capture, acoustic, electromagnetic, and other technologies, allows and helps athletes perform movements at a minimum (Hanley et al., 2018).

### *2.4.1. Performance Analysis and Development*

Motion capture technology analyzes athletes' movements in detail and evaluates their performance. Factors such as athletes' technical errors, accuracy of trends, strengths, and weaknesses are detected. This data helps coaches create personalized training programs and help athletes improve their performance. Movella company has a software product called M.V.N. Analyze, which is produced for athlete performance analysis. With this software and Xsens motion capture equipment, the accuracy of the data on the athlete's movements is guaranteed to improve the quality of the work of specialists in ergonomics, rehabilitation, biomechanics, or sports sciences. Figure 17 shows an image of the use of the respective products (M.V.N. Analyze, 2023).

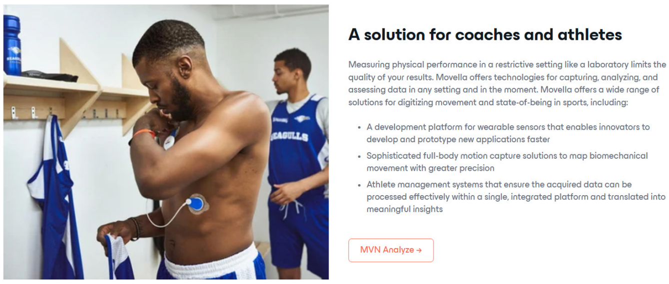
**Figure 17.** *An Image of the Use of M.V.N. Analyze Software and Xsens Equipment (M.V.N. Analyze, 2023).*




### *2.4.2. Technical Training and Training Simulations*

Motion capture technology is used to offer athletes more effective technical training. Athletes learn the correct techniques by performing accurate movements with motion capture systems. At the same time, thanks to virtual simulations, they can train in different conditions. Movella's Analyze software and Xsens motion capture equipment that can be connected can provide a working environment based on technical data for coaches and athletes. Figure 18 shows an example of using body sensors manufactured by Xsens in an athlete (M.V.N. Analyze, 2023).

**Figure 18.** *An Image of M.V.N. Analyze Software and XSens Body Sensors (M.V.N. Analyze, 2023).*




Thai boxing is a martial art that is a heritage of Thailand. This app aims to explore the development of Thai martial arts and provide training in self-defense, combining knowledge and fun. There are 30 stances in the Thai boxing exercises. This work uses visual and auditory elements such as edutainment, 3D characters, scenes, animations, emotions, interactions, movements, virtual reality, and simulated situations to attract students' attention. The moving image was captured using two optical motion capture devices to record the correct activities. Care was taken not to interfere with the performance of dangerous postures. The developed system was found to help students with a good level of physical education to develop an interest in Thai culture, exercise postures, physical activities, and self-defense techniques (Phunsa et al., 2009).

### *2.4.3. Motion Biomechanics*

Motion capture is also used to study the motion biomechanics of athletes. In this way, the conformity and efficiency of the athletes' movements with physical principles are analyzed. This data can help athletes reduce their risk of injury. Xsens motion capture sensors and M.V.N. Analyze software can be used in this context. Thanks to the data obtained, it can be evaluated using technical data whether the athletes perform the movements correctly or not (M.V.N. Analyze, 2023). Figure 19 shows the Xsens equipment installed for the acquisition of technical data of a Rugby athlete.

**Figure 19.** *An Image of the Use of M.V.N. Analyze Software and Wearable Xsens Equipment (M.V.N. Analyze, 2023).*

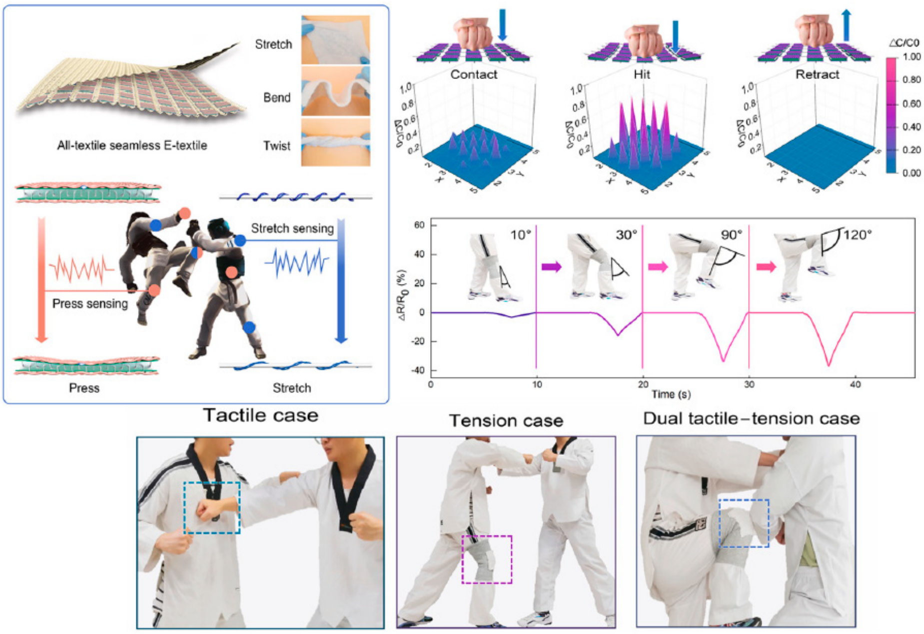
### *2.4.5. Game Analysis and Tactics*

Motion capture is used for game analysis and tactical development in team sports. Players' positions, movements, and interactions on the field are analyzed in detail. This analysis can be used to optimize the team's tactical approach. G.P.S. and L.P.S. technologies track players' positions, but some regulations limit these systems to training environments. These regulations prevent players from being tagged with tracking sensors during soccer matches. However, as G.P.S., L.P.S., and image-based player tracking technologies improve and regulations are relaxed, applied sports scientists can more accurately measure individual movements (Glazier, 2017).

### *2.4.6. Physical Preparation and Exercise*

Motion capture technology creates athletes' physical preparation and exercise programs. The best training plans can be created by analyzing the athletes' body mechanics, flexibility levels, and conditioning. Figure 20 shows the work done using motion capture equipment for training and physical purposes (De Fazio et al., 2023).

**Figure 20.** *Use Motion Capture Equipment In Training And Physical Preparation (De Fazio et al., 2023).*

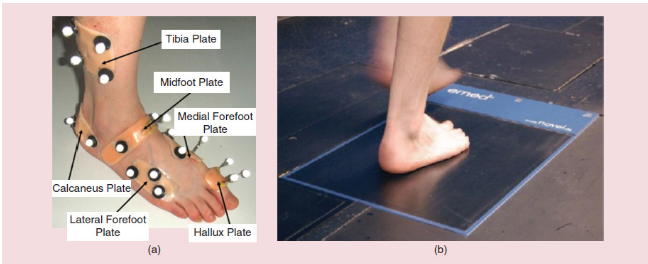



### *2.4.7. Injury Prevention and Rehabilitation*

Quantitative assessment of kinetic parameters, range of motion, and heart rate can be used in respiratory rate, sports performance monitoring after injury or surgery, and rehabilitation monitoring. Wearable sensors are an emerging technology for post-rehabilitation and sports monitoring applications. Assessing a patient's physical condition, the level of rehabilitation training, and the quality of rehabilitation effects is crucial in the recovery process. Collecting a range of data (e.g., movements, flexion, joint rotation, etc.) can help provide important monitoring feedback to the user. This data allows the correct treatments to be identified and their effectiveness and the patient's progress to be evaluated (De Fazio et al., 2023).

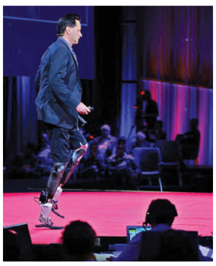
Whatever your favorite sport, your favorite athletes have probably suffered some injury during training or live competition. Even if it is a small quantity of fun in your spare time, if it does not heal properly, it can cause injuries that will haunt you for a long time. Injury rates are much higher in high-impact sports such as football, soccer, wrestling, and hockey than in running and swimming. A study of 15 varsity sports found that about 50% of reported injuries were sprains, followed by ligament or tendon inflammation and bruises. With the technical data obtained from the biomechanical analysis, the range of motion can be determined by personalizing the movements prohibited for these injuries on behalf of the athlete in terms of prevention and healing. Figure 21 shows the motion capture equipment used to make special footwear for an athlete (Bandeiras, 2019).

**Figure 21.** *Use Motion Capture Equipment To Make Special Shoes For An Athlete (Bandeiras, 2019).*




In addition, implants and prosthetic devices used in sports are becoming increasingly sophisticated. Prosthetic devices for athletes with disabilities must be adapted to the specific sport and are often not practical for everyday life. Design and material considerations are being studied for each athlete; more advanced prosthetic devices are 3D printed and manufactured with electromyography sensors to encourage movement intent similar to a normal limb. One of the pioneers of this technology is Hugh Herr, a professor of biomechatronics at the Massachusetts Institute of Technology. After losing his bionic limbs in an ice-climbing accident, the Technology Media Lab developed equipment for the missing limbs. These analyses enabled the standard measurement through a comprehensive replication of human gait. Figure 22 shows an example of the study (Bandeiras, 2019).

**Figure 22.** *Hugh Herr Demonstrated A Bionic Prosthesis (Bandeiras, 2019).*



## 2.5. Education Sector

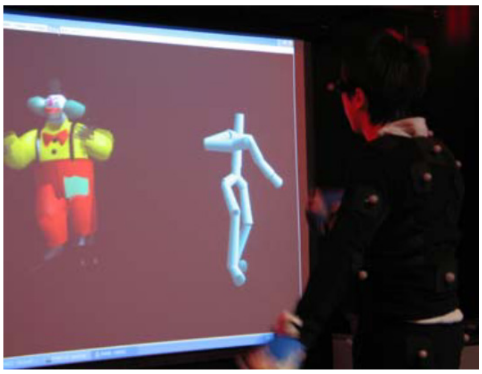
Motion capture technology gives students more effective, interactive, and tangible experiences in the education sector. This technology makes learning processes more fun, easier to understand, and meaningful while providing teachers different learning methods and tools. In this context, usage examples in the education sector were examined under the following sub-headings.

### *2.5.1. Art Education*

The motion capture technique, which is widely used today, is used in many different fields, such as music, dance/performance, sign language, gesture perception, rehabilitation/medicine, biomechanics, biomedical, robotics, video games, anthropology, virtual reality, special effects of action movies, computer animations and athletic performance analysis, human-computer interaction. This technique is mainly used in the spirit of surreal characters, action movements, and animal characters in the film and game industry. Studies using motion capture techniques in education have generally focused on dance education and educational games. Within the scope of the European Open Dance Project, a three-dimensional simulation of folk dances was made. First, the conceptual model and learning model focusing on the requirements of dance education were applied; then, local dances in various parts of Europe were digitized using the optical motion capture technique. The interaction of teachers and learners with animated dancers was provided on the three-dimensional web platform. It has been stated that teachers, learners, and experts find the developed learning environment attractive. The data compiled in the computer environment were used to show the dance figures, practice, and get feedback through the virtual reality device. According to the results of the pre-test and post-test, it was stated that the application increased the dance skills of the learners. Another study used the motion capture technique to index human body parts. In addition, it has been observed that it successfully determines unwanted movements (Büyük, 2022).

In another study, a virtual lesson education system was developed, and dance education was preferred because it allows performances where body movements can be watched the most. In the developed system, the “Virtual Teacher” shows the student the standard dance template of the action, and the student acts by imitating it. The student’s 3D movement is captured by the camera, which is an optical motion capture system. The virtual education system screen has a virtual teacher’s avatar on the left and a student’s virtual avatar on the right. The student tries to imitate the movement of the virtual teacher with his avatar. The system continues to capture and update the teacher’s training. The student’s poses also allow the avatar to move accordingly simultaneously. The system will analyze this movement data, and the virtual teacher will report what is wrong with the student’s performance. An example screenshot is given in Figure 23 (Chan et al., 2007).

**Figure 23.** *Using Motion Capture Technology, an Image from a Virtual Dance Training System (Chan et al., 2007).*



Good posture is essential for successful musical performance, and music teachers put much effort into improving their students’ posture. A study evaluated a skeletal motion capture system (based on Microsoft Kinect ™) to help teachers provide feedback to students on their posture and movements while playing an instrument. The work also included a participatory design phase, resulting in a radically redesigned prototype that replaced skeletal motion capture with an interface that allows teachers and students to draw on video, supported by computer vision tracking (Gillies et al., 2015).

In another study by Rahman et al. (2011), a magnetic motion capture system evaluated a pianist's soft and dexterous finger movements while playing the piano with musical notes. It was observed that the pianist played the piano intermittently according to the letters, and it was seen that he maintained a similar timing ratio and timing order for individual fingers while playing the piano. Accordingly, the position of the finger could be determined using these data. This way, beneficial information could be compiled for the system users (Rahman et al., 2011).

### *2.5.2. Digital Labs*

Motion capture technology provides students with experience in a digital laboratory environment, enabling them to understand concepts in biology, physics, or chemistry courses without practice. This technology helps validate optimisation-based digital human models through experimentation. Studies conducted at the *Human-Centred Design Research Laboratory* at *Texas Tech University* used an eight-camera motion capture system. Bone landmarks were highlighted, and segments were identified by placing markers on the subjects. The resulting joint angles were mapped onto digital human models. Laboratory studies analyzed the movements of pregnant women, such as jumping, standing, lying down, walking, sitting, and lying in different positions. The motion capture system is a method used to test the accuracy of optimisation-based digital models. These studies have made significant progress in enabling students to learn concepts without experience and improving the reliability of digital human models (Cloutier et al., 2011).

A motion capture lab can capture 3D motion and, in some cases, associated analog data. Further analysis of the recorded data is possible using professional software. The lab used as an example in our research is located at the Lublin University of Technology and is equipped with the highest level of equipment. Eight cameras have a maximum frame rate of 512 Hz at full resolution. They provide real-time motion capture. The lab setup also includes a wireless E.M.G. system and two bio-mechanical platforms. This laboratory is the only one of its kind in eastern Poland. There are only nine similar research centers in other parts of the country. The limiting factor preventing motion capture labs from becoming more popular is the high equipment cost (Skublewska-Paszkowska et al., 2015).

### *2.5.3. Medical Education*

Medical students can access virtual training platforms where motion capture technology is used to simulate surgical procedures and gain realistic experiences. Physical models have long been used as a substitute for actual anatomy in medical teaching. These models do not decompose; they can be studied at leisure, and they are materials that have proven to be teaching aids. Virtual models are built on this integrity, as they are easy and inexpensive to share and publish electronically, although they are expensive to produce. It also has the potential to allow students to have simulated surgery experiences without posing any danger to patients, and it can give tactile feedback to students through tactile interfaces. 3D modeling and animation also allow for visualizing subjects and scenes that could never have been filmed (Büyük, 2022).

*Virtual reality (VR)* is an emerging technology that could drastically change traditional medical training and surgical techniques. The level of real-time interaction distinguishes VR applications from other computer systems. In *Virtual Environments (VE)*, users are immersed in artificially generated environments. The perception of sound also contributes to immersion in a virtual environment. An ideal VE for patient care will integrate all available information about a patient into a single model, including medical images, biochemical analysis, and patient history. Using simulations is one of the most attractive applications of virtual reality in medicine. VR. Simulations can be used to train and certify surgeons, especially in complex procedures such as minimally invasive medicine. The availability of medical simulators for training surgeons and medical students will be a crucial application of VR in medicine. Virtual and augmented reality systems are not limited to diagnosis, planning, and simulation but can also help during surgery (Wieben, 2001).

### *2.5.4. Customized Training*

A game was developed by Newcastle University using the motion capture technique to help rehabilitate patients who had suffered a stroke, and interaction between the players and the game was provided. The study emphasized that the success of e-learning depends on using educational materials that provide high-quality content and distribution. As a method of high-quality distribution, it has been stated that learning can be realized with teacher avatars that keep learners focused on speaking and moving. Two main approaches can be used in the animation of characters: manual animation and motion capture technique. However, it has been said that the motion capture technique requires special equipment and skilled employees to create the animation (Büyük, 2022).

## 2.6. Industry Sector

There are many areas where motion capture can be used industrially. In 1984, the first character animation using the technique was created for a commercial commissioned by one of the largest canned food manufacturers in the United States. This evolved into a commercial called *Brilliance*, or *Sexy Robot*, broadcast during the *Super Bowl Championship* in 1985. Although impressive, the use of this technology took some time to become widespread in the communications field, gaining strength in the late 90s as the technologies became more efficient and accessible (Tiago, 2016).

### *2.6.1. Use of Motion Capture Technology in Product Design and Prototyping*

Motion capture technology can move quickly and effectively through product design processes. Capturing user movements in product design is very important regarding usability and ergonomics. In addition, real-world movements can be faithfully simulated when developing product prototypes. Microsoft, the manufacturer of the Kinect sensor, describes it as *a physical device that can detect people's voices, their locations, and movements, has depth perception, a color camera feature, an infrared emitter, and an array of microphones*. The Kinect sensor has found many uses thanks to its gesture recognition feature. Important data provided by Kinect includes the X, Y, and Z coordinates of the detected points and the distance of objects from the camera. Kinect tracks the positions and distances of human joints to capture body movements in three dimensions and also offers facial recognition and voice recognition. When it starts, Kinect first emits infrared rays to check if people are in its field of view. Kinect then detects the human skeleton in the camera's field of view and performs motion recognition. In this case, Kinect transmits gestures to the system that overlap with the motion patterns stored in system memory. In their study, Prabhu et al. (2014) developed a model that can dynamically align for the assembly of the wheels of vehicles. The study designed a concept in which optical measurement is carried out using infrared light and depth imaging for automatic control. Low-cost infrared depth imaging devices like the Kinect are intended to track a moving wheel hub and recognize its alignment characteristics. The proposed method is thought to enable the automatic wheel loading operation and the automation of many assemblies in motion (Boyacı et al., 2017). Figure 24 shows the Microsoft Kinect device components (Microsoft Kinect, 2023).

**Figure 24.** *Microsoft Kinect Device and Components (Microsoft Kinect, 2023).*

Figure 25 illustrates an example of using a Microsoft Kinect device to digitize the operating interaction of a compressor (Microsoft Kinect, 2023).

**Figure 25.** *We Are Examining the Compressor Operation Interaction with the Microsoft Kinect Device (Microsoft Kinect, 2023).*


### *2.6.2. Using Motion Capture Technology in the Assembly and Production Line*

Assembly processes on the production line require accurate and precise movement. Motion capture technology allows workers to act more accurately and consistently during assembly. This, in turn, reduces errors and improves production quality. As an example of current practice, as shown in Figure 26, technical data for use by the BMW Group to improve worker ergonomics was collected with Movella and XSens equipment (M.V.N. Sports, 2023).

**Figure 26.** *BMW Uses Xsens Motion Capture Equipment to Improve Ergonomics (M.V.N. Sports, 2023).*


In another study, Improper working postures on a conveyor line were analyzed with the *AnyBody Modeling System (A.M.S.)* to determine the strains on the musculoskeletal system during human-machine interaction. The motion information given as input to the A.M.S. was obtained by motion capture systems. The operations and working stops on the eight assembly tables on the wiring harnessing conveyor line were recorded with four cameras at a frame rate of 30 fps and statically analyzed by allowing the human model to reflect the situation on the assembly line. In addition, the bending and bending angles of the employees in the waist, neck, and arm areas were measured with an anthropometric protractor, and video recordings were taken simultaneously. Among the 252 working postures in the video recording, which are included in the video recording, two different working postures with high bending and bending angles and the most challenging for the employees were focused. At the end of the study, a workbench with a more ergonomic structure according to the workers' posture was suggested. Images of the work done in Figure 27 are given (Gönen & Atıcı, 2021).

**Figure 27.** *Detection Of Postures Of Workers Working On The Bench Using The Motion Capture Technique With A Camera (Gönen & Atıcı, 2021).*

### *2.6.3. Using Motion Capture Technology in Human-Machine Interaction*

Safety and efficiency are essential when industrial machines and vehicles interact with humans. Motion capture technology is used to make human-machine interaction safer and more effective. Operators' movements and positions are monitored, thus minimizing safety risks. Movella's Xsens Motion Capture Solution is a product that can unlock invaluable insights to optimize workplace efficiency, safety, and well-being by precisely capturing and analyzing human movement in real-life working conditions (M.V.N. Sports, 2023). Figure 28 shows Xsens motion capture equipment on a factory machine.

**Figure 28.** *Using Xsens Motion Capture Equipment in a Factory Environment (M.V.N. Sports, 2023).*

## 3. Results and Conclusion

Today, computer technology is involved in almost all of our lives. Computer technologies, which can find their place in many areas, from simple ordering to complex scientific calculations, can take data from many sources as input, process them, and make them useful for humanity.

Data transfer to computers can be directly from peripheral devices such as keyboards and mice or connecting analog or digital-based sensors. Today, many features of people, animals, or tools, such as movements, images, and sounds, are transferred to the computer environment using such sensors, and these data can be processed using auxiliary software.

Motion capture devices are a data digitization system developed in response to such a need. Thanks to these devices, the required behavior of all kinds of moving or non-moving assets can be digitized measurably. These behaviors can sometimes be done as a measurement of the entity's appearance, its dimensions, its expansion, the vibration it emits, the accelerational state of its movement, the angle of the movement, etc.

Developing sensor technology solves the needs of human beings in this direction more and more daily. For example, technological developments such as the increase in the image capture speed and capture resolution of a camera and the ability of a sound sensor to detect higher frequencies contribute to this process.

Motion capture devices and techniques are also developing in parallel with this development. Not a day goes by that we do not witness another new use of motion capture techniques. In this research, the types and usage areas of motion capture devices in the sector have been tried to be explained with examples.

Being a workspace sensitive to developing technology, motion capture systems have the potential to change in the future and capture an even more effective use in our lives.

There may be a need for many experts in developing and using motion capture systems, which are so important. For this reason, including and explaining these devices in the educational environment at all levels of education will create different awareness for students. In this way, training new experts and contributing to developing these experts' technology will be possible.

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CHAPTER

3

# Artificial Intelligence and Immersive Reality: A Systematic Literature Review on Research in the Social Sciences[1]

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## Introduction

In this section, we delve into two noteworthy technological advancements in recent years: immersive reality and artificial intelligence (AI), examining them through the profound perspectives of social sciences. Immersive reality invites individuals into an inclusive and interactive simulation world, while artificial intelligence contributes to humanity's speed and efficiency across various fields, from processing big data to complex decision-making processes and the development of effective automation systems. These advanced technologies, by pushing the boundaries of traditional social science methodology, have the potential to offer unprecedented solutions and insights.

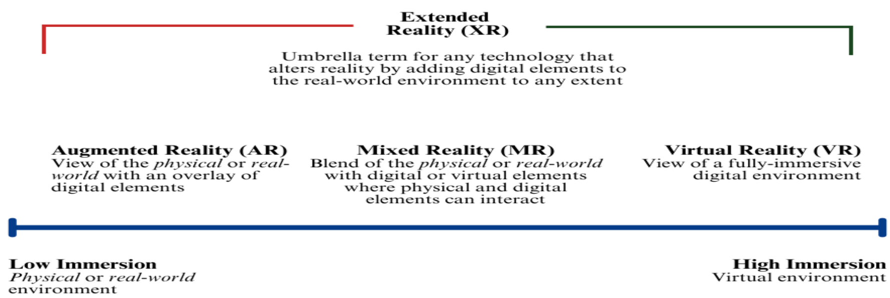
The section consists of two main parts: The first part details the foundations, developmental processes, and fundamental features of immersive reality and artificial intelligence, illustrating how these technologies have brought about a transformation in the field of social sciences. The second part conducts a systematic literature review on how these technologies are used together in the realm of social sciences. It deeply analyzes existing studies that provide applied solutions and theoretical contributions to real-world issues. In conclusion, this section aims to help us understand how the integration of immersive reality and artificial intelligence in social sciences has generated innovative strategies in research, application, and policy-making, and how this synergy could influence societal dynamics in the future.

## Immersive Reality

Immersive technologies are a range of technologies that blur the boundaries between the real and virtual worlds, creating a deeper sense of immersion and enhancing the user's virtual experience  (H. G. Lee et al., 2013). This concept is used to refer to different technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Immersive technologies provide opportunities for subjects such as experiencing situations in situ, real-time data collection, or evaluating events from different perspectives. On the other hand, these technologies face various challenges in terms of usage. Factors such as access cost, potential biases of the society using these technologies, or ethical concerns related to privacy and security can limit the use of these technologies.

Immersive technologies can be placed on an immersion spectrum based on the levels of immersion. This spectrum ranges from Virtual Reality (VR), which offers users the opportunity to experience a fully virtual environment, to a scale where virtual elements are integrated with the real world (Figure 1).

**Figure 1.** *VR, AR ve MR teknolojilerinin daldırma spektrumu*




**Source:** Interaction Design Foundation - IxDF, (2017)

### *Virtual Reality*

Despite being one of the recent technological trends, Virtual Reality (VR) has been in existence since the 1960s (Wohlgenannt et al., 2020). Generally, VR is defined as "A technology that creates a virtual immersion in a digital environment through a computer graphics simulation that allows users to immerse themselves in an interactive three-dimensional world in which they encounter different kinds of sensory and emotional experiences" (Villena-Taranilla et al., 2022). Due to advancements in technology, the increasing use of VR is attributed to factors such as reducing costs, increasing accessibility, and providing a more realistic user experience. As a natural consequence of the rising adoption rate, VR is widely preferred in various industries such as healthcare (Fertleman et al., 2018), education (Richter et al., 2022), tourism (H. Lee et al., 2020) and the fashion industry (Yaoyuneyong et al., 2018).

Based on the sense of presence it creates in users, VR can be categorized into immersive VR and non-immersive VR (Suh & Lee, 2005). In immersive virtual reality, user interaction with the virtual environment is facilitated through wearable devices, while in non-immersive virtual reality, this interaction is achieved through a monitor (Kim et al., 2017).

### *Augmented Reality*

Augmented Reality (AR) is a set of technologies that enables the integration of digital content with the real world. Extending from virtual reality to the real world, AR is often defined as an enhanced view of the real world environment enriched with information generated by a computer, typically in the form of graphics or sound. AR is not limited to just auditory and visual aspects; it can also include components such as touch and even smell (G. K. Lee et al., 2021). In this context, AR has various versions and types, but they share some common elements, including input devices, displays, tracking devices, and computers (Carmigniani et al., 2011). The tools mentioned are required for the user to perceive the information provided in digital environments as reality. The combination and use of these components vary depending on the type of application being developed (Berryman, 2012). Augmented reality can manifest itself in various forms in every aspect of life. For example, there are many studies focused on making educational activities more engaging and enduring through AR.

### *Mixed Reality*

Mixed Reality (MR), which blends virtual content with the real world, is based on similar principles as AR technology. It is called mixed reality because it encompasses AR, VR, and holographic technologies. In virtual reality, the real world is seen in a virtual environment, while augmented reality involves the placement of objects in the real world. Mixed reality allows for simultaneous interaction with the real world through virtual elements. The main distinction from AR lies in the devices used for visualizing information. AR relies on the use of tablets or smartphones, whereas MR is implemented using devices like headphones or glasses. Another difference is that MR does not immerse the user entirely into a virtual environment, unlike VR. MR brings together the virtual and real worlds simultaneously, allowing users to interact with objects without physically touching them (Speicher et al., 2019).

### *Extended Reality*

Extended Reality (XR) is essentially a different form of Augmented Reality (AR). In a broad sense, XR encompasses AR, VR, and even MR technologies (Rauschnabel et al., 2022). XR represents new environments where both virtual and real worlds coexist, allowing digital and physical objects to interact with each other (Cook et al., 2023). able 1 provides comparisons of AR, VR, and MR from the perspective of human-compute r interaction.

**Table 1.** *Comparison of AR, VR and MR in terms of human computer interaction*

| | AR | VR | MR |
|---|---|---|---|
| **User** | The user and surrounding people | The user | The user and surrounding people |
| **Task** | Situations where combined experiences of real and virtual content is beneficial and possible | Situations where the physical or story context does not exist, is not accessible to a user or where the actual physical context is not desirable | Situations where combined experiences of real and virtual content is beneficial and possible |
| **Interface** | Simulation Technology, Display Technology, Computer Graphics Technology, Computer Graphics Technology, Registration Tracking Technology | Simulation Technology, Display Technology, Computer Graphics Technology | Simulation Technology, Display Technology, Computer Graphics Technology, Registration Tracking Technology |
| **Context** | Everywhere | In a “secure” area or in specific contexts | Everywhere |

| | | | |
|---|---|---|---|
| **Interaction** | User and virtual model, User and physical space | User and virtual model | User and virtual model, User and physical space, Physical objects and Virtual models |

**Source:** *(Ke et al., 2019; Rauschnabel et al., 2022).*

Research suggests that a clear distinction, especially in the conceptualization of new realities, needs to be made between AR (Augmented Reality) and VR (Virtual Reality). The commonly used differentiation between AR and VR is often based on hardware features. However, studies recommend making this distinction based on the user experience and evaluating it in the context of human-computer interaction (Rauschnabel et al., 2022).

## The Importance of IR in Social Sciences

Immersive technologies have been embraced for a long time due to their accessibility and ease of use. As a result of this adoption, they have gained a significant place in various disciplines, including the social sciences. Considering the nature of social sciences, which requires the examination of the human and societal aspects of events, it is an undeniable fact that the use of these technologies in this field has many benefits. These technologies assist in overcoming the challenges faced in sociological and psychological studies that require fieldwork, and even in ordinary times, they enable the collection of reliable data on human behaviors through realistic simulations. This becomes particularly crucial during extraordinary situations such as the Covid-19 pandemic (Han et al., 2022). On the other hand, in cultural studies that require a certain cost, immersive technologies allow works from different cultures to be examined in virtual environments (C. A. Chen & Lai, 2021). Thus, it becomes possible to introduce closely the social, political, economic, etc., factors of many communities located at distant distances. In addition, the use of these technologies is highly beneficial in the education and teaching of social sciences. Especially in disciplines based on the past, such as history, experiencing events and locations realistically can lead to better understanding of the subject by students and, consequently, an increase in academic achievements (Parong & Mayer, 2021).

## Artificial Intelligence (AI)

Artificial Intelligence (AI) is a field of science focused on developing various products and programs to perform tasks that require rational thinking and behavior. AI encompasses a wide range of areas, including natural language processing, expert systems, robotics, machine learning, and fuzzy logic. The diverse application and research areas within AI focus on different aspects of artificial intelligence.

Natural language processing, which relies on understanding and interpreting human language, is used in applications such as sentiment analysis and chatbots (Ligeza, 1995). Expert systems, another subfield, involves transferring human expertise to intelligent devices and computers using knowledge and rule-based Systems (Buchanan & Smith, 1988). In the rapidly evolving field of robotics, AI techniques aim to integrate with mechanical systems, creating smart machines and devices with autonomous or low-level human intervention (Sutton & Barto, 1998). Machine learning applications, utilizing various algorithms and statistical methods for processing and interpreting data, are widely used in solving classification problems such as disease diagnosis, error prediction, and image recognition, as well as in clustering analyses. Fuzzy logic, replacing the binary classical logic approach, is considered a significant and positive step in the evolution of Science (Zadeh, 2008). It provides benefits in solving multi-dimensional and complex problems by fuzzifying values between two values in classical logic.

In today's world, the discipline of artificial intelligence (AI) is ubiquitous, and collaborative efforts with the field of psychology are underway to generate theoretical explanations for the psychology of artificial intelligence (Derin & Öztürk, 2020). Detecting the behaviors and thoughts underlying artificial intelligence is crucial for both the field of artificial intelligence and psychology. In this context, reality technologies provide users with a realistic virtual world that can be seen, heard, and reshaped, along with an interactive human-computer interface open to interaction with real-world objects (Zheng et al., 1998).

The development of Augmented Reality (AR) and Virtual Reality (VR) technologies, which combine real-world objects with virtual environments, is greatly influenced by various artificial intelligence (AI) Technologies (Sahu et al., 2021). After the development of Virtual Reality technology, Augmented Reality technology enhances the virtual world by enriching it with the real world. An interactive environment is provided by adding virtual objects onto real-world images (Kato, 2012). In applications encompassing both VR and AR technologies, known as Mixed Reality (MR) or Karma Gerçeklik (KG), simultaneous interaction with created virtual objects and data is facilitated. Lastly, Extended Reality (XR) technology combines these three reality types—Augmented Reality, Virtual Reality, and Mixed Reality—into a unified experience (Alizadehsalehi et al., 2020).

Artificial Intelligence (AI), based on the transfer of rational or human-like behavior and thought processes to systems, plays a crucial role in the development and enhancement of reality technologies. The integration of AI techniques with virtual reality technologies, widely used in various fields such as education, healthcare, entertainment, and the military, enables intuitive and natural interactions (Berryman, 2012). AI techniques are utilized in the processing of vast amounts of data obtained in reality technologies, addressing complex problem-solving, advanced perception, prediction, classification, and clustering processes. Examples of AI applications include motion-based interactions in the entertainment sector, object recognition in the military, creating instructional environments in education, and error reduction in industrial processes.

Reality technologies provide users with the opportunity to experience a sense of reality, creating a new perception environment distinct from the real world using various devices. Consequently, data obtained through reality technologies is collected and analyzed. Reality technologies play a significant role in applications and research across various fields such as education, psychology, sociology, history, and tourism. Particularly, by enriching user experiences and simulating situations that could be encountered in the real world, these technologies contribute significantly. For instance, in a study conducted in the field of tourism, a virtual environment inspired by a typical village in Kenya's Masai Mara region was created. The provision of a three-dimensional virtual environment in the study was noted to have an impact on the behavioral intentions of tourists in trip planning (Huang et al., 2016). In the field of psychology, reality technologies are utilized to simulate social situations, aiming to enhance social skills, conduct controlled experiments, and obtain reliable results. For example Anderson et al., (2013) applied virtual reality exposure therapy for social anxiety disorder, indicating the effectiveness of exposure to virtual reality in treating social fears.

The use of reality technologies is increasing in the field of education, similar to tourism and psychology. It is emphasized that these technologies contribute positively to enhancing the learning experience and potential by providing interactive learning environments with tangible experiences (Bulu, 2012). Additionally, the main motivation for the use of these technologies is highlighted as the opportunity to experience and live through physically inaccessible situations (Freina & Ott, 2015). An example study focused on the use of virtual reality technologies in astronomy education. The study indicated that astronomical events, when visualized through virtual reality technology, were presented in an effective and efficient learning environment by providing access to unique experiences (Kersting et al., 2023). Parong & Mayer, (2021), examined the effectiveness of Immersive Virtual Reality (IVR) technology in understanding lessons by comparing it with a video shown on a computer monitor. Participants watched a history lesson as a 3D interactive video in both IVR and desktop monitor settings. The results showed that participants who watched the video lesson were more successful than those who watched the IVR lesson. According to electroencephalography (EEG) measurements, the IVR lesson provided lower cognitive engagement. Another study investigated the impact of AR/VR technologies on corporate business processes and human resources management. The research focused on how these technologies could be used to optimize business processes such as education, evaluation, and operational processes. The study emphasized that the use of these technologies could help companies achieve leadership positions in national and international arenas (H. Zhao et al., 2019).

## Artificial Intelligence Applications and Case Studies in Immersive Reality

Immersive Reality (IR) is an expensive type of Virtual Reality (VR) that gives users the impression that the virtual worlds and events they experience are real (H. G. Lee et al., 2013). In many virtual reality environments today, the visual experience is processed on a computer monitor. However, in an Immersive Reality (IR) system, the user is completely surrounded by a three-dimensional digital world and feels like a part of it (Özdemir, 2017). Gaddis, (1997), provides a definition of virtual reality as a computer-generated simulation depicting a three-dimensional environment that affords users the capacity to observe, modify, or engage with. Immersive virtual reality environments, in particular, divest users of any semblance of the tangible world, engrossing them entirely within the virtual milieu crafted by the computational system.

The fundamental attributes of virtual reality environments can be delineated as follows: a) three-dimensional visualization, b) the capacity for active interaction within the virtual environment, and c) provision of visual and auditory feedback (Mantovani et al., 2003). These features come together to make users feel that they are part of a simulated experience and allow them to experience it firsthand (Kilmon et al., 2010). Some of the application areas of Immersive Reality, defined as a technology that alters the user's perception of the real world, include:

**Education:** Immersive reality offers students an interactive learning experience. For example, reenacting a historical event gives students a chance to experience the atmosphere and events of that period.

**Entertainment:** Immersive reality can be used in entertainment areas such as video games and virtual reality experiences. Users can experience scenarios that are not possible in the real world.

**Health:** Immersive reality can find applications in therapy and rehabilitation. For example, it can be used to work on the brain and nerves of a paralyzed patient.

**Business:** Immersive reality can assist businesses in effectively showcasing their products and services to customers. For instance, an automotive company could provide customers with an immersive reality experience allowing them to feel what it's like inside a vehicle.

**Military:** Immersive reality can be employed in military training and simulation. Military personnel can be trained in a simulated environment to learn how to respond in a hazardous situation in the real world.

The study conducted by Wang & Sun, (2022) focuses on the design and implementation of interactive virtual reality software based on artificial intelligence deep learning algorithms. The goal of the study is to enhance the interaction capabilities of artificial intelligence in a virtual reality environment. The development of an interactive glove is emphasized, utilizing a nine-axis accelerometer and deep learning algorithms such as KNN, SVM, Fuzzy, PNN, and DTW. The developed glove not only enables static and dynamic gesture recognition but also performs real-time analysis of gesture sequence data. In addition to providing insights into the design and implementation process, the study presents test results for virtual reality gesture recognition.

Ma, (2021) discusses the application of virtual reality (VR) technology-based interactive contextual teaching methods for English instruction at the university level.

The aim of the study is to enhance students' English learning abilities by creating an interactive learning environment using VR technology. The results of a comparative teaching experiment conducted in two different first-year university classes are presented in the study. The experimental class receives VR-based interactive contextual teaching, while the control class undergoes traditional teaching methods. The results indicate that the experimental class outperformed the control class in listening, speaking, and overall performance. Additionally, a survey revealed that most students in the experimental class could adapt to the immersive teaching method embedded in VR. The study highlights the potential of integrating artificial intelligence and machine learning to enhance language education with technology.

Over the past 25 years, research has consistently demonstrated the efficacy of Virtual Reality (VR) as a valuable tool in both the treatment and assessment of mental health. The term "biomarker" pertains to an objectively quantifiable physiological, pathological, or anatomical characteristic that elucidates, influences, and/or predicts outcomes related to health (Coravos et al., 2019). In accordance with this definition, "digital biomarkers" encompass datasets comprising objectively measurable physiological and behavioral data acquired and assessed through digital technologies, employed to elucidate, influence, and/or predict health-related outcomes (Piau et al., 2019).

The utilization of Virtual Reality (VR) facilitates the direct acquisition of digital biomarkers pertaining to behavior within virtual environments, along with the retention of diverse digital biomarkers correlated with distinct physiological state attributes intricately linked to said behavior. VR operates by integrating follower data and the content of a simulated 3D world, creating a model of the body and the surrounding area. In drawing parallels to the cognitive processes of the human brain, the Virtual Reality (VR) system employs simulation to anticipate the sensory outcomes of an individual's movements, mirroring the cognitive mechanisms inherent in the brain (Riva, 2018). The objective of VR is to closely emulate the cognitive model of the brain, and the greater the resemblance between the VR model and the brain, the stronger the individual's sense of integration into the VR environment (Riva, 2018; Sanchez-Vives & Slater, 2005).

The direct connection between VR and brain function makes VR a "concrete technology" that can update the user's body experience (Riva et al., 2019). This feature allows VR to be used as an enhanced therapeutic digital tool for correcting dysfunctional predictive coding mechanisms in the brain. Studies have shown that the predictive and simulative mechanisms in the brain may be responsible for various neurological and psychiatric conditions (Riva et al., 2017). The ability of VR to directly collect digital biomarkers linked to brain functionality and its adaptability to modifying dysfunctional predictive coding mechanisms in our brains have allowed technology to address these deficiencies effectively.

## Method

A systematic literature review is a research methodology designed to methodically identify, assess, and amalgamate all accessible evidence pertaining to a particular research question or topic. The undertaking of a systematic review constitutes a pivotal preliminary phase before embarking on any research study. It establishes the groundwork for understanding, fosters the development and enhancement of theories/models, addresses research lacunae, and unveils areas that may have been disregarded by preceding studies (Marangunić & Granić, 2015). In this research, a systematic search was conducted following the guidelines proposed by Kitchenham, (2004).

A systematic literature review entails the strategic formulation of a search plan, its execution, and the subsequent dissemination of the review outcomes. The identification of research questions and data sources occurs during the initial planning phase of the study. In the review stage, the process commences with the delineation of a search strategy and terminologies, followed by the establishment of selection criteria applied to individual studies. Subsequently, procedures for evaluating study quality, extracting data, and synthesizing results are systematically employed. The reporting phase encompasses the composition and presentation of the findings.

Systematic reviews are considered a high level of evidence because they use rigorous methods to minimize bias and ensure the consideration of all relevant evidence. They are widely used in informing policy and decision-making processes in health, social sciences, and other fields (Aytekin et al., 2022).

PRISMA stands for Preferred Reporting Items for Systematic Reviews and Meta-Analyses. It is an acronym for a widely recognized and accepted reporting guideline that provides a standardized checklist for reporting systematic reviews and meta-analyses (Liberati et al., 2009). The PRISMA statement consists of a 27-item checklist and a flow diagram that assists researchers in transparently reporting various stages of their systematic reviews, from the initial exploration and screening of studies to the synthesis of findings.

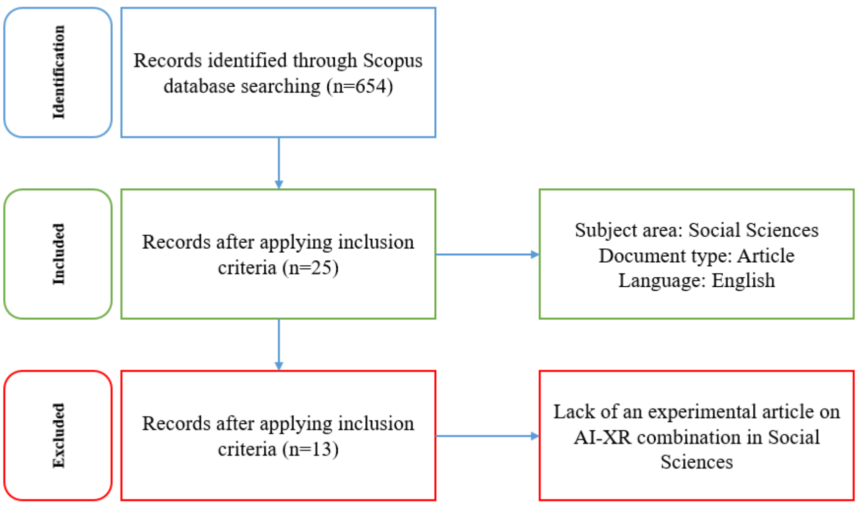
## Search strategy and article identification

A literature review was conducted using the Scopus database, following the guidelines established by the PRISMA protocol. The primary search terms ((“Virtual reality” OR “Augmented reality” OR “Mixed reality” OR “Extended reality”) AND (“Artificial intelligence” OR “Machine learning” OR “Deep learning” OR “Neural network*”)) were applied on October 15, 2023. As a result of the search strategy, 654 studies were filtered.

## Inclusion and exclusion criteria

The suitability analysis assessed the literature based on three fundamental criteria: 1) subject area, 2) article type, and 3) publication language. The inclusion and exclusion criteria are provided in Figure 2 below.

**Figure 2.** *PRISMA-based flowchart of the retrieval process*



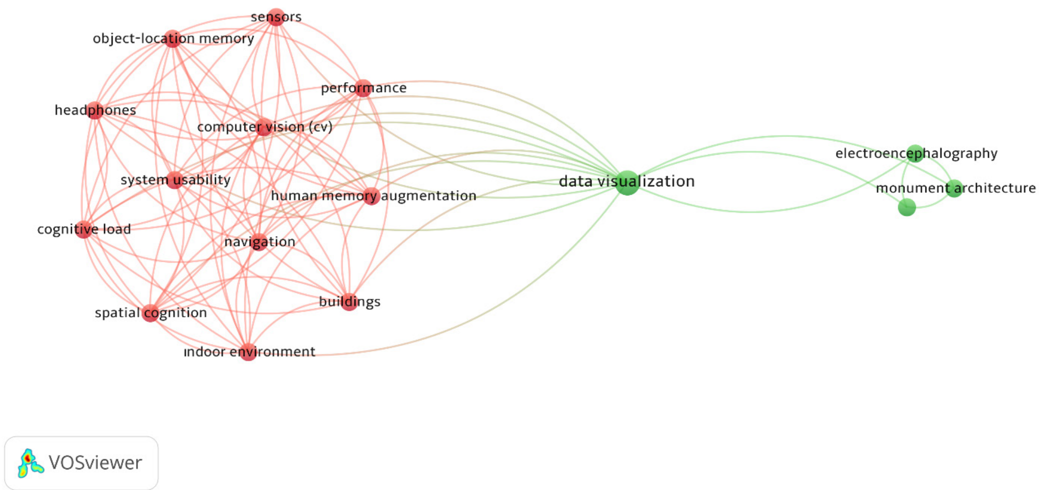

Upon examining Figure 2, articles were retained if they involved an experiment, evaluation, or study related to artificial intelligence and virtual reality in the social sciences. Preference was given to field research articles as the type of articles. Lastly, only articles written in English were retained. Articles in the social sciences that did not involve a literature review on AI-XR or were not experimental studies were excluded.

## Results

As delineated in Table 2, our systematic review has identified 15 published records that encompass the amalgamation of Artificial Intelligence and Information Retrieval (AI-

IR) within the realm of social sciences. Keyword co-occurrence maps were generated to scrutinize the incorporated articles. The VOSviewer software (https://www.vosviewer.com/, accessed on November 1, 2023) was employed to visually represent bibliometric data as a network, as illustrated in Figure 3. In this representation, nodes signify specific terms, their sizes correspond to frequencies, and connections signify the co-occurrence of terms within the keywords of the incorporated articles.

**Figure 3.** *The map of the co-occurrence of the words in the author keywords of included papers*




Upon examination of Figure 3, it is observed that articles related to AI-XR applications are divided into two main clusters with specific topic headings. Terms associated with the red cluster include sensors, performance, human memory augmentation, buildings, indoor environment, spatial cognition, cognitive load, headphones, object-location memory, computer vision, system usability, and navigation. These terms represent a cluster focused on enhancing the technical performance of AI-XR applications and enriching the user experience. On the other hand, terms associated with the green cluster include data visualization, EEG, architectural structures, and stress. These terms represent a more specific and emotionally focused cluster, such as AI-XR visualizing EEG data and transferring architectural design to a virtual environment. The combination of these terms reflects that AI-XR research covers a wide range of topics and interacts particularly with social science areas such as technology, cognitive psychology, architecture, and usability.

**Table 2.** *Included papers*

| References | Abstract | Application | AI Method | XR Platform | Category |
|---|---|---|---|---|---|
| Sung et al. (2021) | Examines the effects on consumers of an AI-integrated MR exhibition in a retail and entertainment complex. It combines high-tech entertainment with shopping. | Consumer Behavior and Retail | Machine Learning | Mixed Reality | Conferring Intelligence on XR |
| Pfeiffer et al. (2020) | It aims to classify shopping motivations using eye tracking and machine learning. It includes two experiments in physical stores and virtual reality shopping environments. | Consumer Behavior and Retail | Machine Learning | Virtual Reality | Interpretation of XR Generated Data |
| Kalatian and Farooq (2021) | It seeks to understand pedestrian and automated vehicle interactions using virtual reality. It uses machine learning and VR to explore the factors that influence pedestrian crossing behaviors. | Transportation and Traffic Safety | Machine Learning | Virtual Reality | Interpretation of XR Generated Data |
| Divekar et al. (2022) | Introduces a multi-modal language learning application using AI and XR. Includes a study on Chinese language learning. | Education and Language Learning | Artificial Intelligence | Extended Reality | Training Artificial Intelligence |
| Li et al. (2022) | It uses VR and deep learning technologies to measure the perception of pedestrian-friendly streets. | Transportation and Traffic Safety | Deep Learning | Virtual Reality | Interpretation of XR Generated Data |
| Cui (2022) | Investigates the use of augmented reality applications in piano teaching. | Education and Language Learning | Artificial Intelligence | Augmented Reality | Training Artificial Intelligence |
| Ji et al. (2020) | It tries to estimate stress rates using VR and EEG data. | Improving Memory and Cognitive Processes | Deep Learning | Virtual Reality | Conferring Intelligence on XR |
| Zhao et al. (2021) | Develops a weightless mobile outdoor AR method. | Improving Memory and Cognitive Processes | Deep Learning | Augmented Reality | Training Artificial Intelligence |

| | | | | | |
|---|---|---|---|---|---|
| Chen et al. (2022) | It is a study on robot-assisted language learning. It integrates the use of AI and VR in English tour guide practice. | Education and Language Learning | Artificial Intelligence | Virtual Reality | Conferring Intelligence on XR |
| Zhang (2020) | Designs a VR and AR based mobile platform and game user behavior tracking system. | Consumer Behavior and Retail | Deep Learning | Virtual Reality and Augmented Reality | Conferring Intelligence on XR |
| Liang et al. (2021) | Develops a LOS method for evaluating bicycle facilities in China's metropolitan areas. | Transportation and Traffic Safety | Deep Learning | Virtual Reality | Conferring Intelligence on XR |
| Spallone and Palma (2021) | Examines how AR and AI are used in the interpretation and understanding of architectural artifacts. | Architecture | Artificial Intelligence | Augmented Reality | Conferring Intelligence on XR |
| Makhataeva et al. (2023) | Introduces the human memory augmentation system using augmented reality, computer vision and artificial intelligence. | Improving Memory and Cognitive Processes | Artificial Intelligence | Augmented Reality | Training Artificial Intelligence |

When examining Table 2, the article's objectives, application areas, artificial intelligence methods, the reality environment used, and categories are provided.

## Discussion

### Application Areas

The combination of AI-XR has found various application areas in social sciences. Among these areas, Consumer Behavior and Retail, Transportation and Traffic Safety, Education and Language Learning, Improving Memory and Cognitive Processes, and Architecture stand out.

#### *Consumer Behavior and Retail*

Sung et al., (2021) investigated the impact of an MR exhibition integrated with AI in a retail and entertainment complex on consumers. This study represents a significant step towards understanding changes in consumers' shopping and entertainment experiences within their social and cultural contexts. Pfeiffer et al., (2020) aimed to classify shopping motivations using eye tracking and machine learning. This research contributes to the effort to understand factors influencing consumers' shopping decisions. Zhang, (2020) contributed to understanding the interaction of consumers with technology through games by designing a VR and AR-based mobile platform and a game user behavior tracking system.

#### *Education and Language Learning*

Divekar et al., (2022) introduces a multimodal language learning application that includes a study on learning the Chinese language using artificial intelligence and augmented reality. This application can contribute to the field of social sciences by exploring topics such as language learning, cultural interaction, and the societal role of language. Y. L. Chen et al., (2022), a robot-supported language learning approach is presented, integrating artificial intelligence and augmented reality into an English tour guide application. The use of technological applications in language learning can offer a perspective to social sciences on how language is learned in cultural and societal contexts. Cui, (2022) addresses the use of augmented reality applications in piano instruction, focusing on the use of technology in education for both music and language learning. In the context of social sciences, the article examines the effects of technology-supported music education and the social interactions impacting student motivation.

### *Transportation and Traffic Safety*

Liang et al., (2021) developed a service level method to assess bicycle facilities in metropolitan areas of China. This study contributes to the social sciences by evaluating the social impacts of bicycle facilities and understanding the role of bicycle usage within society. Kalatian & Farooq, (2021), aim to understand pedestrian and automated vehicle interactions using virtual reality. This research, conducted in the fields of traffic safety and urban planning, seeks to comprehend the social impacts of interactions between pedestrians and automated vehicles. Li et al., (2022) aim to assess pedestrians' environmental awareness and traffic safety using virtual reality and deep learning technologies. Awareness in traffic is crucial for pedestrian safety. From a social sciences perspective, the article examines social interactions related to traffic safety by focusing on human behaviors, perceptions, and interactions.

### *Improving Memory and Cognitive Processes*

Ji et al., (2020) includes a study using virtual reality (VR) and electroencephalography (EEG) data to predict stress levels. It aims to assess cognitive processes and stress coping strategies. In the context of social sciences, the article examines the impact of stress on cognitive processes and evaluates the social effects of technology use on individuals' mental health. G. Zhao et al., (2021) introduces a mobile outdoor augmented reality (AR) method for memory enhancement. It focuses on improving the learning experience using deep learning and knowledge modeling techniques. In the context of social sciences, the article investigates the effects of technology-supported learning methods on memory and cognitive processes. Makhataeva et al., (2023) introduces a system aiming to enhance human memory using augmented reality (AR), computer vision, and artificial intelligence (AI). It focuses on memory enhancement and cognitive processes. In the context of social sciences, the article evaluates the impact of technology use on individuals' memory and cognitive processes. These articles address the integration of technology by focusing on memory and cognitive processes. From a social sciences perspective, they contribute research in areas such as mental health, learning experiences, and the social effects of technology.

### *Architecture*

Spallone & Palma, (2021), present an example demonstrating how technology can be integrated into efforts to understand and preserve cultural heritage. Such projects can offer rich insights to the social sciences in understanding the interaction between science, technology, and culture.

The above-mentioned studies illustrate how the combination of AI and XR can be utilized in various fields within the social sciences. Understanding the social impacts of these studies is crucial for comprehending society's interaction with technology and guiding future research endeavors.

## Determination of Categories

The articles in Table 2 have been classified into three categories presented by Reiners et al., (2021): 1) Interpretation of IR Generated Data (n=3), 2) Conferring Intelligence on IR (n=6), and 3) Training Artificial Intelligence (n=4).

### *Interpretation of data generated by IR*

The three articles in the category of "Interpretation of data generated by IR" generally focus on the analysis and interpretation of extensive datasets obtained from IR technologies. These studies have examined how data generated using IR technologies can be assessed and how the acquired information can be given meaningful interpretations. While each article may have its unique emphases and methods, the overall focus in the "Interpretation of data generated by IR" category has been on transforming the data produced by IR technologies into meaningful insights. This can occur in various contexts such as user performance, shopping behaviors, and traffic safety.

Pfeiffer et al., (2020), demonstrate the usability of eye-tracking technology, utilizing eye-tracking data in VR and the physical environment to determine shopping motivations (goal-oriented and exploratory). VR is used to track users' eye movements in a shopping environment and interpret motivations based on these movements. Kalatian & Farooq, (2021) examine the effects of the presence of autonomous vehicles on pedestrian crossing behavior. They collect and interpret rich behavioral data using VR. VR is employed to create experiences in scenarios not present in a real environment, allowing observation and interpretation of participants' behaviors. Li et al., (2022) propose a VR and deep learning framework to measure visual walkability perception and assess visual features. VR provides participants with the opportunity to experience city streets in a virtual environment, while deep learning is used to measure and interpret visual features. All three articles suggest different methods for interpreting and making sense of data obtained using IR technology. IR is utilized as a powerful tool to enhance participants' experiences and better understand the acquired data.

### *Conferring Intelligence on IR*

The phrase "Conferring Intelligence on IR" implies enhancing the IR experience by incorporating artificial intelligence (AI) into IR tools, aiming to provide more effective communication and interaction capabilities. In this context, we can elaborate on this topic by examining the mentioned studies.

As indicated in the text, the integration of AI into IR can offer various advantages in different application areas. Ji et al., (2020) addresses a stress prediction model using virtual reality and deep learning. This enhances the ability to measure and interpret emotional states using electroencephalography (EEG) data within IR. This approach holds the potential to determine stress levels and improve user experience. Y. L. Chen et al., (2022) aims to enhance English tour guide applications using artificial intelligence and virtual reality. This involves using AI in an IR application focused on language learning to provide an interactive language learning experience. Zhang, (2020) discusses tracking mobile platform and game user behaviors using virtual and augmented reality with deep learning. This aims to better understand and optimize user interaction within IR by employing deep learning algorithms. Liang et al., (2021) aims to assess bicycle service levels using virtual reality and deep learning technologies. This involves integrating deep learning techniques to evaluate the performance of urban bicycle facilities through real-world simulations. Spallone & Palma, (2021) explores how artificial intelligence and augmented reality technologies can enhance built heritage. Through different projects, it examines how AI-supported IR can be used in cultural heritage preservation, restoration, and interpretation. Sung et al., (2021) focuses on increasing consumer interaction using interactive artificial intelligence and mixed reality. It explores how these technologies are used in a complex setting within the retail and entertainment sectors. These studies highlight the applications of artificial intelligence within IR, demonstrating that integrating AI technologies into IR can enrich the user experience and increase the potential for usage in various industries.

### *Training Artificial Intelligence*

The concept of "Training AI" emphasizes the training of artificial intelligence systems using real-world data. In this context, we can expand on this topic by looking at other referenced studies and examples.

Divekar et al., (2022) addresses foreign language learning using artificial intelligence and augmented reality. In this context, the study explores how artificial intelligence can be used to simulate real-world language applications and optimize language learning processes. It highlights the potential of AI-supported augmented reality applications to create virtual environments where language learners can interact, simulate real-world experiences, and enhance language learning effectiveness. Makhataeva et al., (2023) focuses on enhancing human memory using augmented reality and artificial intelligence. The study investigates how artificial intelligence can contribute to learning processes and memory development by simulating real-world objects and scenarios. The aim is to facilitate learning and improve memory by enabling interaction with real-world experiences. Cui, (2022) addresses the use of artificial intelligence and creativity in piano instruction through augmented reality applications. By simulating real-world piano experiences and employing AI-supported learning methods, the study explores the potential of providing interactive and innovative learning opportunities for students. G. Zhao et al., (2021) explains how mobile outdoor augmented reality technology can be used to enhance the learning experience. The study explores strategies to enrich the learning experience and enable more effective learning by simulating real-world outdoor environments and detecting learning scenes using deep learning techniques.

## Conclusion

As a result, this article comprehensively reviews the intersection of Artificial Intelligence (AI) and Immersive Reality in the field of social sciences. Adhering to the PRISMA guidelines and using the designated keywords, 13 articles meeting specific inclusion criteria were identified. The reviewed articles were classified into three categories: 1) Training Artificial Intelligence, 2) Conferring Intelligence on IR, and 3) Interpretation of data generated by IR. Additionally, we defined the fundamental applications of AI-IR combination technologies, covering areas such as Improving Memory and Cognitive Processes, Architecture, Transportation and Traffic Safety, Consumer Behavior and Retail, Transportation and Traffic Safety and Education and Language Learning. The findings of this study emphasize the increasing significance of the connections between AI and IR technological developments in the field of social sciences, indicating promising future expectations for widespread applications in social science domains.

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CHAPTER

# Introducing Animals Living in the Poles: An Educational Game Example

4

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## Introduction

In Türkiye, 50 years ago, in 1967, the late Prof. Dr. Polar scientific studies, which started with Atok Karaali, gained momentum in the 2000s. It started to take shape with the first national Antarctic science expedition in 2017 under the auspices of the Presidency and with the responsibility and support of the Ministry of Science, Industry and Technology. Future polar scientific studies will gain a clear direction through this workshop organized at Istanbul Technical University (ITU) in order to become a national science program "with the status of a state strategy of the Republic of Turkey" and to be sustainable for polar research (Polar Sciences Workshop, 2017).

The poles are the northernmost and southernmost areas of our planet. Even though we are not very close to the Polar Regions geographically, we follow the developments in the Polar Regions closely. For this purpose, the National Polar Science Program (2018-2022) has been prepared with the vision of being among the leading countries with original scientific studies on polar sciences in the world. One of the goals is to ensure bilateral cooperation on polar sciences and to send our scientists to the science bases of other countries. In accordance with the goals of the program, polar awareness should be created among our country's children. These scientists will be among our children, today's children and tomorrow's adults.

Living creatures in nature have developed protection and survival mechanisms against hot/cold climate conditions, limited food resources and natural disasters, and in this way, it has become possible for approximately 3 million species to survive to the present day (Sivri, 2017). Some of these animals also survive in the Polar Regions. Polar ecosystems are the ecosystems that are most dramatically affected and reacted by environmental changes, especially climate change (Özkan, 2018). With the effect of global warming, the shrinking of sea ice in the open seas and many climatic changes negatively affects the hunting and feeding habits of polar region animals. By introducing polar region animals, we want to raise awareness about climate change and help expand research on the habitats of these animals.

Educational games are effective educational tools in terms of making educational environments fun and ensuring permanent and effective learning. Educational games provide a physical and virtual environment that offers learners specific goals and existing procedures (Akgün, 2011). With the opportunities offered by technology, research and development studies on computer games have accelerated in recent years. In addition, computer games, which are the subject of academic conferences, meetings, studies and books, are expressed as appropriate applications aimed at learning (Gee, 2003).

Efforts by countries to assert themselves in the Polar Regions have accelerated in recent years. Türkiye is involved in the process with its Polar Research studies. In order to raise human resources in line with our country's goals, educational environments should be organized in accordance with these goals and individuals should be raised with the appropriate awareness. Teaching polar region animals to secondary school students through an educational game, although it may seem small, will be an important step in achieving our country's goals. Our study is thought to be important in this respect.

The aim of the research is to enable secondary school students to recognize animals living in the Polar Regions. Animals living in Polar Regions are not recognized by students at secondary school level. It started with the hypothesis that if polar region animals are introduced to secondary school students through an educational game, effective and permanent learning can be achieved.

## Method

After determining our research topic, research was conducted on topics such as the Polar Regions, animals living in the Polar Regions, and Türkiye's polar policies. Although not many sources can be accessed, it has been determined that there have been more studies in the last five years. Since there was no educational game about animals living in the Polar Regions that appealed to secondary school students, it was decided to conduct a study in this field.

The research was conducted using the scanning technique, one of the quantitative research methods. In the scanning approach, it is aimed to describe the event, individual or object subject to research as it exists in its own conditions (Karasar, 2008, p. 77). Data collection tools are pre-survey form, post-survey form and self-evaluation form. In data analysis, graphs were created by analyzing the data using simple statistics. The data collection process took one week. The participants of the research are 33 volunteer students at the 5th grade level studying at a school in Ankara. 15 of the participants are girls and 18 are boys. The conversations held during the application and the participant observer observation notes will also be mentioned in the conclusion section.

In the study, animals living in Polar Regions were determined. An information card was prepared with the characteristics of animals. Colored images of the animals were printed and used as models. Images of the designated animals were made with colorful beads. For this purpose, tiny colored beads were placed on plastic trays in accordance with the images of the animals. Animal image prototypes were created by placing wax paper and heating and fixing the beads using an iron. The back parts of the animal prototypes were magnetized with the help of hot silicone. 12 prototypes were made. Because one more item is placed in matching games so that the last two items will not match each other. Information cards for the 11 animals identified were arranged in a Word document and printed out. The printouts were passed through the laminating machine and cut. The backs of the information cards were magnetized using a hot glue gun. A board with magnetic legs was provided and animal prototypes made of beads and information cards were placed on the board and our physical educational game was ready to be played for matching purposes.

An online version of the game has also been made using information technologies. For this purpose, pictures of animal prototypes made of beads were taken. These visuals were placed with the content of an educational game in the programming language using Scratch software, and the information on the information cards was written. Educational game software has been developed where matching is the basis.

An announcement was made introducing our project to the parents of 5th grade secondary school students studying at our school, and sessions were held where participation was voluntary. Students who participated voluntarily were asked: ‘Do you know polar region animals? The question was posed. The majority of the 33 students who participated in the research answered ‘disagree’. The justification for our research is the answers given. Graphs will be included in the findings section.

An application was carried out in which participating students came one by one. The physical version of the educational game on a magnetic board was placed in the classroom. The online version prepared in Scratch software language was opened on the smart board. Students were taken into the classroom individually and first they were allowed to play the material version of the educational game. Then, they were allowed to play in the Scratch software on the smart board. At the end of the application, students were given a self-evaluation form. The self-evaluation form was prepared with the help of an academician who is an assessment and evaluation expert. The self-evaluation form, prepared on Google form, was filled in by the participants via the computer in the classroom after the application. Form results will be included in the findings section. At the end of the application, the final survey form was applied to the students who completed the self-evaluation form and the resulting graph was included in the findings section.

Participants who completed the self-assessment form were given a piece of paper and asked to choose one of the animals and write a story about the future of that animal. Participants created different stories using each animal. The results of these stories were also analyzed using content analysis and were planned to be presented as a paper at a suitable congress for the dissemination and sustainability of the project. In the data obtained from the stories, it is seen that the students are conscious about climate change and have hopeful plans for the habitats of animals.

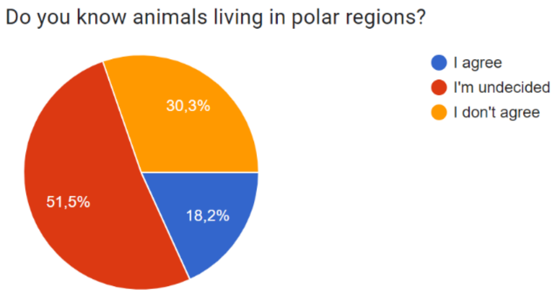
The link to the ready-to-play version of the educational game in Scract software is below. Open the game by clicking on the flag icon at the top left twice. In accordance with the instructions of the game, it is necessary to click on the dots on the right and drag the opened information cards onto the relevant animal picture. Press the space bar twice to fix the white dot you dragged to the animal. After the writing disappears, the same procedure should be done for all animals. If you make a mistake once, you have to play the game from the beginning. To do this, you need to click on the flag icon again. For those who successfully complete the game, the word WIN appears at the end of the game. Copy the link and paste it into the address bar.

https://scratch.mit.edu/projects/683237686/

## Results

Findings obtained from the pre-survey form - final survey form and self-evaluation form were presented in the form of graphs.

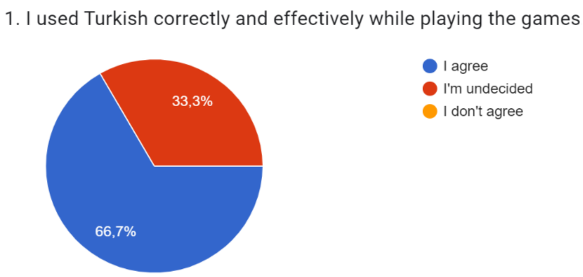
**Figure 1.** *Preliminary Survey Form*




The majority of participants answered that they disagree and are undecided.

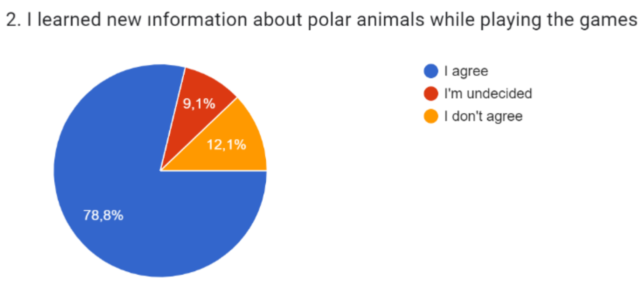
## Findings from Self-Assessment Form Responses

**Figure 2.** *Answer Graph of Question 1*



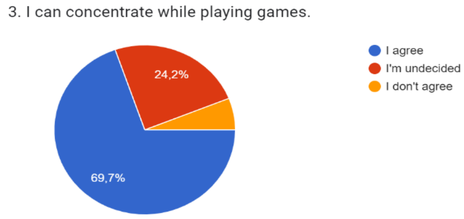

*Explanatory note*: Participants responded to the question "I used Turkish correctly and effectively while playing the games." as follows: I agree 22 people (66.7%), I'm undecided 0 people, Disagree 11 people (33.3%).

**Figure 3.** *Answer Graph of Question 2*



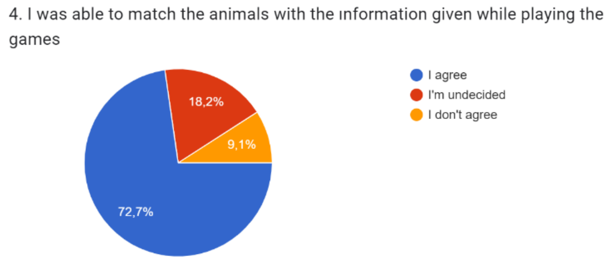
*Explanatory note*: Participants responded the question "I learned new information about polar region animals while playing the games" as follows: I agree 26 people (78.8%), I am undecided 3 people (9.1%), Disagree 4 people (12.1%).

**Figure 4.** *Answer Graph of Question 3*



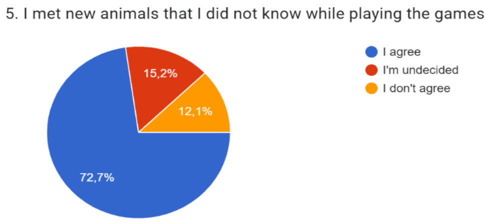

*Explanatory note*: Participants responded "I was able to focus while playing the games." the question as follows: I agree 23 people (69.7%), I am undecided 8 people (24.2%) Disagree 2 people (6.1%).

**Figure 5.** *Answer Graph of Question 4*



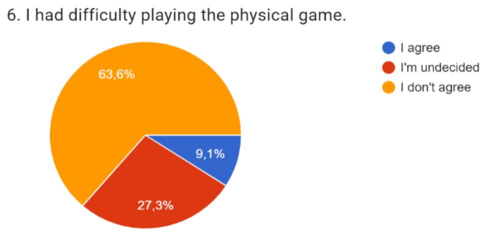

*Explanatory note*: Participants responded to the question "I was able to match the animals with the information given while playing the games." as follows: I agree 24 people (72.7%), I am undecided 6 people (18.2%), Disagree 3 people (9.1%).

**Figure 6.** *Answer Graph of Question 5*



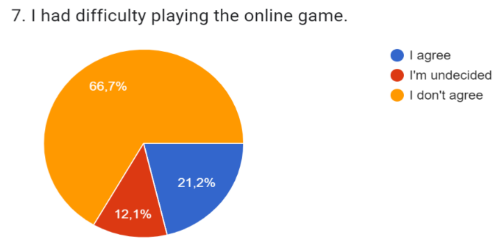

*Explanatory note*: Participants responded to the question "I met new animals that I did not know while playing the games." as follows: I agree 24 people (72.7%), I am undecided 5 people (15.2%), Disagree 4 people (12.1%).

**Figure 7.** *Answer Graph of Question 6*



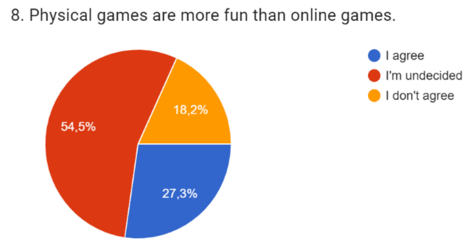

*Explanatory note*: Participants responded to the question "I had difficulty playing the physical game" as follows: I agree 3 people (9.1%), I am undecided 9 people (27.3%), Disagree 21 people (63.6%).

**Figure 8.** *Answer Graph of Question 7*



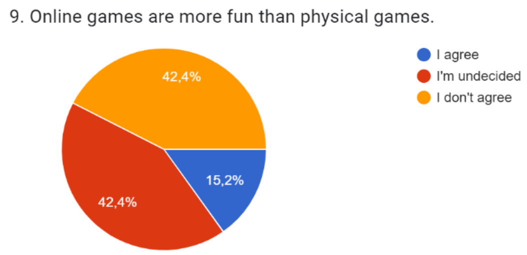

*Explanatory note*: Participants responded to the question "I had difficulty playing the online game" as follows: I agree 7 people (21.2%), I am undecided 4 people (12.1%), I disagree 22 people (66.7%).

**Figure 9.** *Answer Graph of Question 8*



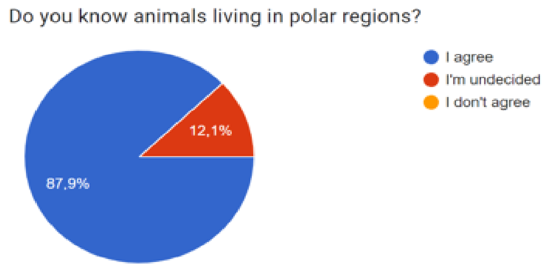

*Explanatory note*: Participants responded to the question "Are physical games more fun than online games?" as follows: I agree 10 people (30.3%), I am undecided 17 people (51.5%), I disagree 6 people (18.2%).

**Figure 10.** *Answer Graph of Question 9*




*Explanatory note*: Participants responded to the question "Are online games more fun than physical games?" as follows: I agree 5 people (15.2%), I am undecided 14 people (42.4%), I disagree 14 people (42.4%).

**Figure 11.** *Graphic of the Final Survey Form*




*Explanatory note*: Of the 33 people who participated in the application, 29 people answered "I agree" in the final survey form, while 4 people answered "I am undecided." No one selected the disagree option.

## Conclusion and Discussion

The number of people who participated in the research voluntarily was 33. 15 of the participants are girls and 18 are boys. All participants are at the 5th grade level. All participants who applied completed the pre-survey form, post-survey form and self-evaluation form.

The reason for our research was that the majority of the participants said they were undecided or disagreed when asked "Do you know the animals living in Polar Regions?" in the preliminary survey form, 29 of the participants answered "I agree" to the same question asked in the last survey form. This shows that my hypothesis has been proven. It can be said that our educational games have served their purpose.

The fact that 22 participants agreed with the question "I used Turkish correctly and effectively while playing the games" in question 1 in Figure 2 of the self-evaluation form shows that the information cards we prepared are clear, understandable and suitable for the Turkish language. It is thought that the correct use of language and instructions in educational games prevents permanent grammatical errors and also affects concentration and understanding. The fact that 11 of the participants said they disagree shows that they had difficulty with the explanations on the information cards and did not understand them. We can conclude that we need to be more careful about language use when preparing different educational games or making different arrangements in educational environments.

Self-evaluation form is shown in chart 32. 26 participants (78.8%) agree with the question 'I learned new information about polar region animals while playing the games', indicating that we included new information and that animal information cards provided participants with information about animals. 3 undecided people (9.1%) indicate that they already know the information, or they do not find the information learned sufficient, or they have not learned the information. We can conclude that 4 people (12.1%) disagree that they did not learn new information, that it did not interest them, or that they already knew it.

The answer to the question 'I was able to concentrate while playing the games' in the 3rd question in Chart 4 shows that 23 participants (69.7%) agree that they prefer to be careful while playing educational games because they attract their attention or they are careful not to lose in the game. Moreover, looking at this result, it can be said that our educational game is remarkable 8 people (24.2%) were undecided about whether they could pay attention or not. 2 people (6.1%) stated they disagree that they could not concentrate. This shows that games have a distracting effect for these people or they are not interesting enough to hold their attention.

In the 4th question in Chart 5, 24 participants (72.7%) said “I was able to match the animals with the information given while playing the games” and stated that the information on the information cards was sufficient to find the animals. 6 people (18.2%) are undecided and they stated that the information cards did not give them a definite idea about animal pairings. Those who said they disagree, 3 people (9.1%), stated that the information on the information cards was not sufficient for them to match animals. We can conclude that we need to add more information to the animal flashcards.

In the 5th question in Chart 6, 24 participants (72.7%) responded “I met new animals that I did not know while playing the games” is an indication that we have achieved our goal. It can be said that our game has achieved its goal in introducing new unknown animals. Since 5 people (15.2%) are undecided, it may be thought that they already know the animals in the game or that the information they obtained from the information cards is not sufficient for them. As 4 people (12.1%) responded “I disagree”, it can be concluded that they already know animals.

In the 6th question in Chart 7, ‘I had difficulty playing the physical game’, 3 participants (9.1%) agree that they had difficulty in the educational game with physical educational material, while 9 undecided participants (27.3%) could not decide whether they had difficulty or not. 21 people having the answer “I disagree” (63.6%) stated that they did not have difficulty playing the physical education material. While these findings cannot reach the conclusion that the educational game is either easy or difficult, it can be concluded that the game instructions are clear, understandable and the animal prototypes reflect reality because the participants did not have any difficulty.

I agree with the statement “I had difficulty playing the online game” in the 7th question in Figure 8. For 7 people (21.2%), they may have had difficulty in playing the educational game on the smart board due to the usage issue, the instructions of the game may not have been clear, and they had difficulty in matching the animal prototypes. The educational game itself may have been difficult. 4 people (12.1%) were undecided about whether they had difficulty or not. It can be concluded that 22 people having the answer “I disagree” (66.7%) do not have any problems in using smart boards and that animal prototypes are easy to use.

10 of the participants (30.3%) said they agreed with the statement “Physical games are more fun than online games” in the 8th question in Chart 9. For these participants, physical educational materials appear to be more entertaining than virtual educational games. It is understood that 17 people (51.5%) could not decide between both games. As 6 people chose the option “I disagree” (18.2%), it can be concluded that virtual games are more fun than physical educational games.

In Chart 10, it can be concluded from the statement “Online games are more fun than physical games” in the 9th and last question of the self-evaluation form that 5 of the participants (15.2%) agree that they find online games more fun. 14 people (42.4%) were undecided about which of the educational games was more fun and could not make a choice. According to the participants who said they disagree, 14 people (42.4%), physical educational games are more entertaining than virtual games. As it can be seen here, secondary school students find concrete games that they can hold with their hands more interesting. It may be thought that the fact that the animals are made of beads has an effect on this. Learning that is touched and felt is more permanent. Even though they are labeled as children of the technology age, it seems that they prefer physical educational games to virtual games, at least in the educational game we designed.

As far as we observed during the application, the participants found the games interesting. Their reactions, especially when they saw the animal prototypes made of beads, and the shape of their faces when touched, show that they enjoyed it very much. Each participant stated that they wanted to play again at the end of the application. They brought their friends and introduced them to games outside the application and had them play with them. We received questions from families about where we got the beads and how we made them. The fact that the students had fun during the process made their families happy and they congratulated us.

Educational games can be developed to suit any subject in educational environments. In this way, effective and permanent learning that attracts students' attention can be achieved. These activities can be enriched with materials and virtual content suitable for each lesson. We had a lot of fun playing the games we prepared ourselves. For this reason, creating fun and happy environments will be beneficial for permanent learning.

## Suggestions

• Polar awareness activities should be increased in order to raise awareness about the Polar Regions.
• Educational games should be included more in educational environments so that permanent and effective learning can be achieved.
• Learning environments should be shaped in line with students' interests and wishes. For this purpose, in addition to the necessary educational materials.
• In order to move our country forward in international polar politics, awareness-raising activities should be carried out in every age group, starting from the new generation, so that different ideas can be obtained in our polar region studies.
• We applied our educational game to 5th grade students, but it can be extended to individuals at every school level and in every professional group.
• All people should be made aware in order to protect the polar region animals, which may become extinct in a short time as a result of climate change, which is one of the most important environmental factors in the world, and to make their living spaces more livable.
• More research should be done on the Polar Regions, Turkish bibliography should be increased and it should be included in the literature in Türkiye.

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## Additional

### Answers to the Self-Assessment Form

1. I used turkish correctly and effectively while playing the games

| | number of people | % |
|---|---|---|
| I agree | 22 | 66,7 |
| I'm undecided | 0 | 0 |
| I don't agree | 11 | 33,3 |
| **Total** | 33 | 100 |

2. I learned new ınformation about polar animals while playing the games

| | number of people | % |
|---|---|---|
| I agree | 26 | 78,8 |
| I'm undecided | 3 | 9,1 |
| I don't agree | 4 | 12,1 |
| **Total** | 33 | 100 |

3. I can concentrate while playing games.

| | number of people | % |
|---|---|---|
| I agree | 23 | 69,7 |
| I'm undecided | 8 | 24,2 |
| I don't agree | 2 | 6,1 |
| **Total** | 33 | 100 |

4. I was able to match the animals with the ınformation given while playing the games

| | number of people | % |
|---|---|---|
| I agree | 24 | 72,7 |
| I'm undecided | 6 | 18,2 |
| I don't agree | 3 | 9,1 |
| **Total** | 33 | 100 |

5. I met new animals that I did not know while playing the games

| | number of people | % |
|---|---|---|
| I agree | 24 | 72,7 |
| I'm undecided | 5 | 15,2 |
| I don't agree | 4 | 12,1 |
| **Total** | 33 | 100 |

6. I had difficulty playing the physical game.

| | number of people | % |
|---|---|---|
| I agree | 3 | 9,1 |
| I'm undecided | 9 | 27,3 |
| I don't agree | 21 | 63,6 |
| **Total** | 33 | 100 |

7. I had difficulty playing the online game.

| | number of people | % |
|---|---|---|
| I agree | 7 | 21,2 |
| I'm undecided | 4 | 12,1 |
| I don't agree | 22 | 66,7 |
| **Total** | 33 | 100 |

8. Physical games are more fun than online games.

| | number of people | % |
|---|---|---|
| I agree | 10 | 30,3 |
| I'm undecided | 17 | 51,5 |
| I don't agree | 6 | 18,2 |
| **Total** | 33 | 100 |

9. Online games are more fun than physical games.

| | number of people | % |
|---|---|---|
| I agree | 5 | 15,2 |
| I'm undecided | 14 | 42,4 |
| I don't agree | 14 | 42,4 |
| **Total** | 33 | 100 |

## Pre-survey form question

Do you know animals living in polar regions?

| | number of people | % |
|---|---|---|
| I agree | 6 | 18,2 |
| I'm undecided | 17 | 51,5 |
| I don't agree | 10 | 30,3 |
| **Total** | 33 | 100 |

## Last survey form question

Do you know animals living in polar regions?

| | number of people | % |
|---|---|---|
| I agree | 29 | 87,9 |
| I'm undecided | 4 | 12,1 |
| I don't agree | 0 | 0 |
| **Total** | 33 | 100 |

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CHAPTER

# Educational Data Analytics:Harnessing Big Data for Higher Education Enhancement

5

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## Introduction

Big data is a phenomenon that is driving paradigm shifts in higher education and opening unprecedented possibilities in educational institutions. Big data has transformed data generation and aggregation in education, becoming a tool for educators and administrators to make more effective, data-driven decisions in the last decade. Higher education institutions are using big data analytics to monitor student performance, optimize educational strategies, personalize the student experience, and improve overall institutional effectiveness (van Leeuwen, 2023). Harnessing big data for higher education enhancement offers a unique opportunity to better understand students' educational processes, improve teaching strategies and optimize the overall performance of institutions. Big data applications aim to break traditional boundaries in higher education and lay the foundations for a more efficient, personalized, and student-centered learning environment. This book chapter discusses the scope of the big data revolution in higher education in terms of educational data applications and aims to detail the application areas of educational data in higher education.

## Educational Big Data

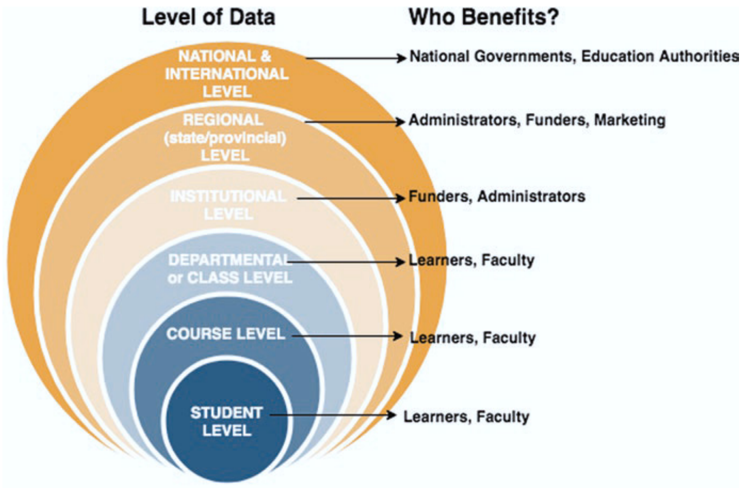
Data are recognized as a crucial catalyst in facilitating transformation in the current era. Big data are large-scale and complex data sets that cannot be stored, managed, and analyzed with traditional data processing techniques. Big data refers to data that is continuously generated from the internet, social media, mobile devices, sensors, cameras, and other sources and needs to be processed. Big data offers new opportunities, insights and value for businesses, organizations, and individuals. The characteristics of big data are defined as 5Vs: Variety, volume, veracity, velocity, and value (Daniel, 2024). These characteristics can be explained as follows:

- **Variety**: Big data encompasses different types and formats of data, whether structured, semi-structured or unstructured. For example, text, audio, video, image, log, GPS, web, social media, e-mail, survey, sensor data. Data from different sources needs to be transformed and integrated to make this data meaningful and useful.
- **Volume**: Big data refer to very large amounts of data. This large amount, usually on the order of terabytes or petabytes, is constantly increasing. Traditional database systems are insufficient to store, process and analyze this data. As a result, there is an ongoing development of new technologies, algorithms, and platforms specifically tailored for applications in big data.
- **Velocity**: Big data refers to fluid and real-time data that is generated very quickly. For example, social media posts, online shopping transactions, live video streams, sensor data. High-performance systems and techniques are required to collect, process, and analyze this data instantly.
- **Veracity**: Big data refers to data of variable quality, reliability, consistency, and accuracy. For example, social media posts, user comments, survey results, sensor data. To analyze this data accurately, processes are required such as data quality, data cleaning, data integrity, data validation.
- **Value**: Big data refers to potentially high-value data. Big data can provide benefits for businesses, organizations, and individuals in areas such as decision making, strategy development, business intelligence, personalized education, customer satisfaction, productivity increase in industrial sectors, and cost reduction. However, to achieve these benefits, big data needs to be analyzed, interpreted, and applied correctly.

Educational settings have big data from many data sources. Students are generating a substantial amount of data as they engage in their studies in the realm of online education. The characteristics of big data also apply to educational big data. It will be useful to explain the 5V of educational big data in detail. Every day, trillions of educational data have been generated in millions of educational institutions in the worldwide. This represents the *volume* characteristic of educational big data. The accelerated emergence of this data corresponds to the *velocity* characteristic of educational big data.

Educational data sources are differentiated in higher education. As known in the literature, educational data are not generated from a single source. A large number of educational data emerges from more than one source. Educational data encompasses a diverse array of information from various sources, including internal data such as school-wide and classroom-specific information, as well as external data from the specific regions (Mougiakou et al., 2023). Figure 1 summarizes the variation of educational data by level and the beneficiaries of this data.

**Figure 1.** *Levels of Educational Data in Higher Education (Long & Siemens, 2011)*




In educational institutions, many different types of data are obtained from many data sources such as teachers, students, administrators, and administrative staff. Data emerges from many different contextual settings such as student-student interaction, student-teacher interaction, behaviors observed in the classroom, personal characteristics and performances of students, relationships between teachers. Various forms of data can be collected, encompassing students' emotional states, demographic characteristics, interaction behaviors within the learning management system. This points to the *variety* characteristic of educational big data.

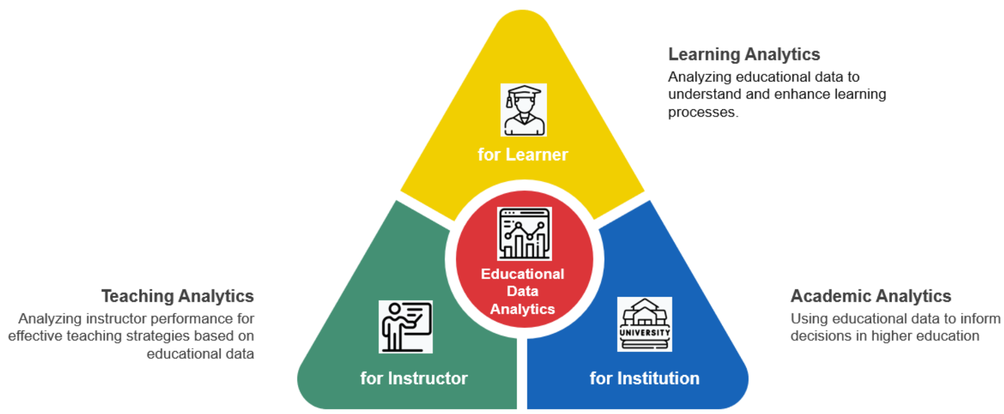
A prerequisite for handling educational big data from so many different sources to ensure the educational big data's *veracity* (Bai, et al., 2021). It is crucial to meticulously choose and implement data sources, collection methods, processing techniques, analysis tools, and interpretation strategies to ensure the precision of educational big data (Li & Jiang, 2021). The *value* of educational big data is a critical aspect to consider. Presently, numerous issues associated with educational big data are being examined, and various scholars are actively engaged in developing applications for educational big data. These applications encompass prediction, recommendation, and evaluation. Specifically, prediction involves forecasting student performance, employment prospects, unemployment rates, and funding availability. Additionally, recommendation focuses on suggesting proper courses, advisors, and job opportunities. Lastly, evaluation concerns the assessment of student academic performance, student emotion, student behavior, teachers' teaching, and research practices (Baiet al., 2021).

## Educational Data Applications in Higher Education

The principles of data-driven decision-making are applicable not only across various sectors but also in education. The volume of educational data related to students, their learning processes, and learning environments has experienced an exponential increase. Educators have the opportunity to leverage the abundance of educational data and the capabilities of data analytics technologies to acquire valuable insights, encouraging creative methods that improve both the learning and teaching processes. Educational data have the capacity to unveil insights pertaining to course design and instructional practices that may otherwise go unnoticed. Moreover, by analyzing educational data, instructors can gain a comprehensive understanding of their students' past, present, and potential future, enabling a profound comprehension of students' activities, behaviors, and preferences. Consequently, educators can skillfully customize their teaching and learning interventions, delivering a personalized learning experience to students, offering improved feedback, and providing the necessary support for them to attain their educational goals. The advantages of educational data are not limited to students and teachers. It also offers unique opportunities for administrators and policy makers of educational institutions.

Harnessing big data in higher education varies according to the source, purpose, and context of the data. In considering the higher education ecosystem and its components, it can be stated that the utilization of educational data will generate valuable information and recommendations for students, teachers, and universities/institutions. In a holistic view, main application areas and concepts have emerged for the use of educational data in higher education in this context such as learning analytics, teaching analytics, and academic analytics. Figure 2 summarizes these concepts.

**Figure 2.** *Educational Data Analytics in Higher Education*




This book chapter will provide information about learning analytics and related sub-fields. The focus of the chapter is harnessing big data for higher education enhancement. It will explain how using educational data in higher education can contribute to students, teachers, and the institution. While not the primary focus of this book chapter, it is important to note that addressing *multimodal learning analytics* constitutes a significant endeavor in the context of utilizing big data to enhance higher education.

## Learning Analytics in Higher Education

Learning analytics is an interdisciplinary research field that has emerged in the last decade. As a concept, learning analytics can be defined as "*the measurement, collection, analysis, and reporting of data about learners and their contexts, for the purpose of understanding and optimizing learning and the environments in which it occurs*" (Siemens & Baker, 2012). Alternatively, learning analytics can be characterized as the systematic analysis and utilization of both static and dynamic data concerning learners and learning environments. This process aims to model, predict in real time, and enhance learning processes and educational settings (Ifenthaler, 2017). As a literal definition, "*learning analytics is the analytics of learning*". The focus has been on addressing challenges linked to the increasing availability, volume, velocity, and diversity of data within learning environments (Lang et al., 2022). It involves the collection, analysis, and presentation of data from the learning environment with the goal of providing evidence regarding the effects of a particular learning design (Stoyanov & Kirschner, 2023). Learning analytics entails the implementation of interventions grounded in the analysis of learner data, with the conviction that such interventions can have a positive impact on both the learning process and the learning environment. It can be conceptualized as the

analysis and representation of data about learners, with the goal of improving learning and providing teachers with a fresh perspective to better understand and advance education (Herodotou et al., 2020). Moreover, learning analytics has demonstrated notable benefits for education, including heightened student engagement, enhanced learning outcomes, early alert for at-risk students, personalization of learning experiences, and provision of real-time feedback (Banihashem et al., 2018). The incorporation of research in both learning design and learning analytics serves as a crucial contextual overlay, enhancing the understanding of observed student behavior. This integration enables the provision of essential pedagogical recommendations, especially in cases where learning behavior diverges from the intended pedagogical goals (Macfadyen et al., 2020).
Visualizing the data related to the learning process and presenting it instantly to the learners is provided by using the learning analytics tools developed. Learning analytics data are used through dashboards to provide meaningful messages about learning processes to learners, instructors and institutions. These specific tools designed for learning analytics are referred to as ***learning dashboards***, with a more targeted scope compared to other reporting tools. Learning dashboards are learning analytics applications based on the visualization and presentation of interaction data in online learning environments to enable students to monitor their own learning processes (Verbert et al., 2013). Learning (analytics) dashboards can be defined as platforms that visualize a large amount of data about learners' learning experiences and present them on a single screen (Schwendimann et al., 2016).

Learning analytics dashboards are categorized into three main categories: descriptive, predictive, and prescriptive analytics (Daniel, 2015; Sampson, 2016). ***Descriptive analytics*** analyze and visualize the data obtained from the learning environment and aim to discover meaningful patterns, while ***predictive analytics*** use student characteristics, interaction data in the learning environment, and past patterns to make meaningful predictions about future learning outcomes (Kokoç & Hayıt, 2020). ***Prescriptive analytics*** aim to provide recommendations on what needs to be done to achieve the targeted learning outcomes and provide inferences that can be directly used in educational decision-making processes (Kokoç & Altun, 2021).

Learning dashboards have recently been used more frequently, especially in higher education institutions that provide online and blended learning (Han et al., 2021; Kokoç & Altun, 2021). These dashboards entail the collection of students' interaction data and the provision of personalized feedback in various formats, including text, visuals, and suggestions (Bodily & Verbert, 2017). Through learning dashboards, learners are provided with real-time, weekly, and monthly feedback (Bodily et al. 2018; Giannakos, 2022) via email, early alerts, and visualization techniques (Altun & Kokoç, 2019) about indicators of learning such as their cognitive performance (Wan et al., 2019), emotional status (Ez-Zaouia, Tabard, & Lavoué, 2020), behavioral engagement (Kokoç & Altun, 2019). Past studies indicate that the utilization of learning analytics dashboards can aid students in developing a deeper self-awareness of their learning progress and help educators identify students who may be encountering learning difficulties (Kokoç & Altun, 2021; Ramaswami, Susnjak, Mathrani, & Umer, 2023). Recent evidence suggests that learning analytics dashboards have the potential to reconnect students with their learning purpose, serving as reminders of their goals and encouraging reflection about their learning journey (Kokoç & Kara, 2021). A recent study concluded that learning analytics dashboards supported collaborative work and improve the collaborative learning experience (Zamecnik et al., 2022). In addition, the design of learning analytics dashboards can be tailored as instructional tools, providing support for the learning process, addressing potential learning loss, and contributing to an increase in learners' attainment of desired learning outcomes (Alam et al., 2023).

Learning analytics, with a focus on reporting data about learners and optimizing learning and the environment, adopts a learner-centric approach. In contrast, teaching analytics is oriented towards aiding educators in analyzing and improving learning designs, both pre and post-delivery, thus positioning its target audience as instructor-centric (Khuzairi et al., 2020).

## Teaching Analytics in Higher Education

Teaching analytics can be defined as "*a new theoretical approach that combines teaching expertise, visual analytics and design-based research, to support the teacher with diagnostic and analytic pedagogical ability to improve the quality of teaching*" (Ndukwe & Daniel, 2020, p.2). Teaching analytics encompasses the methods and digital tools that support educators in analyzing and enhancing learning designs prior to their delivery (Khuzairi, Sidhu, & Cop, 2020). It has the potential to leverage teaching capability. The literature approaches the concept of teaching analytics in two distinct ways. Certain studies involve the examination of educational data to evaluate teacher performance (Ndukwe & Daniel, 2020), while others center on utilizing teacher-facing learning analytics dashboards to process learning analytics data. The goal is to provide teachers with insights for the improvement of students' learning processes (Kaliisa & Dolonen, 2023). Hence, many of these research works portray "*learning analytics for teachers*" rather than "*teaching analytics*" in a literal sense (Prieto, Sharma, Dillenbourg, & Jesús, 2016). Essentially, it yields two significant outcomes: informing learning design and offering real-time feedback on activities transpiring within the classroom (van Leeuwen, 2019; van Leeuwen, Teasley, & Wise, 2022). Bennacer (2022) identified 18 studies specifically centered on teaching analytics in the literature, allowing us to propose a categorization of teaching analytics studies based on objectives, resulting in six goals:

- Feedback about students
- Teachers' behavior analysis
- Recommendation for teachers
- LMS usage analysis
- Course classification
- Teaching evaluation and improvement

Instructors can utilize data derived from their teaching experiences for reflective analysis of pedagogical design, optimizing the learning environment to meet the diverse needs and expectations of students. Applications of educational data empower instructors to make data-driven decisions in ways unprecedented (Singelmann & Ewert, 2022). Teaching analytics can be conceptualized as a rethinking of learning analytics, emerging with a focus on enhancing the quality of teaching and learning outcomes. It takes center stage in technology-enhanced learning (Flavin, 2017). In this context, analytics dashboards, rooted in teaching analytics, possess the potential to assess the performance, make informed decisions, and strategize future activities (Sedrakyan et al., 2020; Williamson & Kizilcec, 2022), owing to the real-time feedback offered on learner performance (Jivet et al., 2021). Teaching analytics tools have the potential to enhance teachers' awareness of student learning and enable them to make informed decisions aimed at improving their teaching.

There are few development studies in the literature within the scope of teaching analytics. One of these research endeavors undertook a case study to examine how machine learning techniques could be utilized to automatically extract teaching actions during the enactment of classroom activities (Prieto et al., 2016). The study utilized five data sources collected through wearable sensors and permitted the automatic detection of the teacher's activity. Regueras et al. (2019) introduced a method leveraging Learning

Management System data to automatically certify teachers' competencies, aiding universities in strategic decision-making. The approach utilized variables linked to both the teacher and students, employing three clustering methods to identify six types of courses used for teacher certification. Van Leeuwen et al. (2019) created dashboards designed for teachers, each providing distinct layers of information (mirroring, advising, and alerting). Another outstanding study utilized a collaborative design approach to create effective translucent learning analytics tools tailored for teamwork in clinical simulations (Martinez-Maldonado et al., 2020). Feedback from four engaged teachers and subject coordinators revealed that the proxy visualizations produced in the process supported teachers in reflecting on their pedagogical methods. In particular, the visualized traces of nurses' activities played a crucial role in refining the learning design. In accordance with a design-based research approach and informed by principles derived from the socio-cultural perspective and human-computer interaction, Kaliisa and Dolonen (2023) created, tested, and appraised a learning analytics dashboard tailored for teachers in authentic educational settings. The primary objective of this dashboard is to aid instructors in online environments by offering insights into students' participation and discourse patterns. Overall, these studies underscore that the primary aim of teaching analytics is to guide educational researchers in developing enhanced strategies that facilitate the improvement of teachers' data literacy skills.

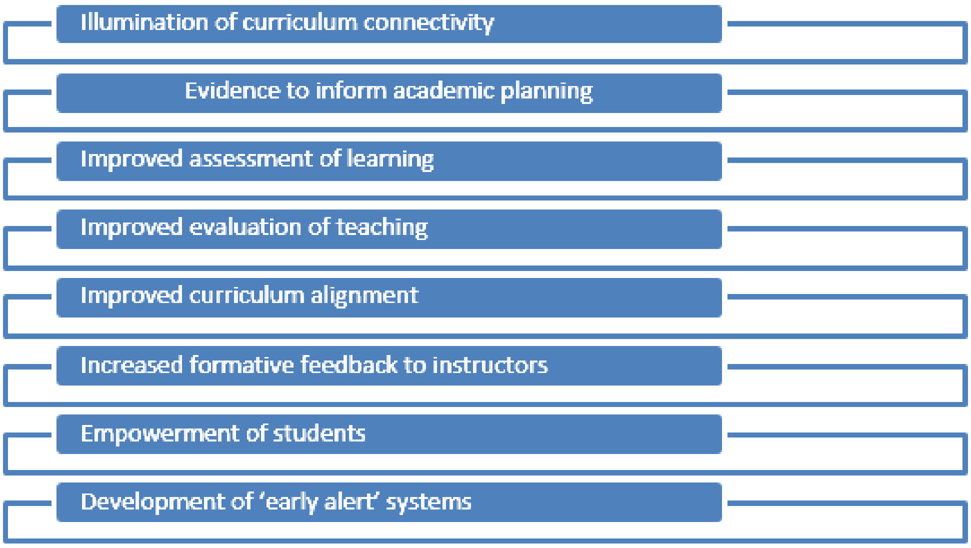
The proficiency of educators in understanding and utilizing educational data which is conceptualized as educational data literacy skills is a crucial factor in attaining the desired results of teaching analytics dashboards. A systematic review study concluded that numerous instructors have continued to face challenges in comprehending and interpreting dashboards, primarily due to a deficiency in data literacy skills and largely attributed to the fact that many tools are designed without involving teachers as collaborative partners (Ndukwe & Daniel, 2020). This result highlights the importance of equipping instructors in higher education with educational data literacy skills. Therefore, it is necessary to develop teachers' educational data literacy skills in the studies to be carried out for teaching analytics in higher education.

## Academic Analytics

Academic analytics refers to the process of discerning significant patterns within educational data in order to develop practical approaches, encompassing the allocation of financial resources and human personnel. In an alternative definition, Academic Analytics is described as the procedure of assessing and analyzing data from university systems, with the purpose of generating reports and supporting decision-making processes (Ferreira & Andrade, 2016). It also serves to provide information on academic matters such as attendance and achievement levels (Ifenthaler, 2017). Academic analytics is viewed within an institutional context, and its outcomes are anticipated to inform the policies of educational institutions. Some studies use the concept of institutional analytics instead of academic analytics (Macfadyen, 2022).

Academic analytics facilitates students and faculty in tracking their career and professional trajectories. It serves as a tool empowering higher education institution to make data-driven decisions across diverse areas, including student success, quality management, promotion, and resource allocation. Academic Analytics involves collecting data on the performance of academic programs to inform policy. It entails utilizing data analysis and interpretation within the academic context to bolster decision-making processes and enhance educational outcomes. It encompasses various analytical approaches such as learning analytics, academic advising, and curriculum mapping (Wang & Orr, 2019; Méndez et al., 2014). For instance, it involves the use of descriptive and predictive analysis in higher education to support operational and financial decision-making (Wang & Orr, 2019). Furthermore, academic analytics can aid in identifying trends and patterns in student performance, which can be valuable for improving teaching strategies and student retention (Howell et al., 2017; Buerck, 2014). Figure 3 presents a comprehensive overview of the fundamental capabilities of learning analytics, exemplifying the wide range of educational stakeholders and objectives that various methodologies can cater to (Macfadyen, 2022).

**Figure 3.** *Affordance of Analytics for Higher Education Institutions (Macfadyen, 2022)*




In addition, with these affordances, it also plays an important role in addressing academic dishonesty behaviors, aiming to uphold the quality of education by mitigating actions that hinder students' creativity and analytical skills (Mulisa, 2016). One example of academic analytics in action is the application of assessment analytics, which provides educators with greater insight into staff and student performance on written assignments (Reed, 2014). Additionally, academic analytics can be instrumental in curriculum mapping within medical and healthcare education, utilizing visual analytics and learning objective databases to enhance the effectiveness of the curriculum (Komenda et al., 2015). Moreover, it has been highlighted those academic analytics, along with learning analytics, is essential for accessing and analyzing large volumes of data in educational organizations, particularly in the context of big data in educational systems (Umezuruike & Ngugi, 2020).

Analytics tools such as Ou Analyse for the Open University (Herodotou et al., 2020), Course Signals for Purdue University (Arnold & Pistilli, 2012) and Lathee for University of Cuenca (Broos et al., 2020) are examples of academic analytics. Course Signals project utilized academic analytics to actively monitor students' performance and engagement in a course, identifying those at risk and sending intervention messages outlining relevant sources of assistance. The tool was designed to enhance student success, retention, and graduation rates (Arnold & Pistilli, 2012). An additional instance of academic analytics is found in the advising dashboard known as LISSA. LISSA stands as a successful example, wherein the advising dashboard, originally conceived through a bottom-up approach to streamline advising dialogues between academic advisors and students, was smoothly incorporated into the institutional systems, processes, and practices of KU Leuven (De Laet, 2023).

Academic analytics have the potential to develop personalized educational programs aligned with students' requirements, enhance academic performance, and offer career recommendations. In addition to academic analytics examining applications at various levels, student-level analytics encompassing teaching effectiveness, financial impact, admission profiles, predictive analysis, post-school employment evaluations, and course recommendations can be undertaken. In summary, academic analytics encompasses a range of analytical methods and techniques that are applied in the academic setting to improve decision-making, enhance educational quality, and support student success. It plays a pivotal role in leveraging data to gain insights into student performance, assessing higher education institutions' performance, curriculum effectiveness, offering career guidance to students, and institutional decision-making processes. Thus, academic analytics in higher education needs to be effectively deployed in quality processes and policy development, contributing to decision-making for improvement and enhancing international visibility.

## Conclusion and Recommendations

The vast volume of educational data presents distinctive opportunities to enhance educational environments and support the learning process. Within this context, there are subfields of research dedicated to analyzing educational data for the improvement of education and learning, aiming to derive practical outcomes. In the literature, diverse concepts surface, encompassing learning analytics, educational analytics, educational data mining, teaching analytics, analytics for learning, writing analytics, and video analytics. In addition, educational data applications can be conceptualized in different ways according to different perspectives. According to Reich (2022), research on learning at scale has provided valuable insights into what can be referred to as "*educational policy analytics*"—studies examining how learners from various life circumstances utilize learning technologies differently. Additionally, there has been exploration into "*education behavior analytics*," investigating how individuals click and engage on online learning platforms. While these concepts focus on different technologies or different user behaviors, their main goal of educational data applications in higher education is to *improve learning by enhancing learning experience*.

The prevailing body of literature on learning analytics research and implementation predominantly revolves around higher education (Macfadyen, 2022). In the realm of higher education, universities and institutions are actively engaging in forward-looking initiatives to leverage the potential of learning analytics, conducting preparatory studies for future implementation, and using cutting-edge technologies (Ifenthaler, Mah & Yau, 2019; Scheffel, Tsai, Gašević, & Drachsler, 2022). This collective effort underscores the recognition of the transformative impact that learning analytics, facilitated through dashboards, can have on shaping the future landscape of education. Data on student performance and preferences can be utilized to create personalized learning journey based on their needs. Student enrollment systems and on-campus data can enhance campus services to better meet student requirements. Interaction data of students in learning management systems and their behavioral and cognitive performance in face-to-face learning environments can be used to predict their success, provide educational interventions, and improve the quality of the learning process.

Learning analytics dashboards using educational data in higher education should incorporate a variety of data sources with different characteristics of the learning process, students, instructors, and stakeholders. In this context, the meaningful integration of data from sub-units within higher education institutions is crucial. It is essential to leverage not only teachers and students, but also administrative transactions and raw data stored in databases. Just as important as data collection and processing is educational data literacy. For studies on educational big data in higher education institutions to fulfill their objectives, faculty members, instructors, administrators, and administrative staff should all possess educational data literacy skills.

In addition to numerous advantages, challenges accompany the implementation of educational data applications and analytics in higher education. One notable challenge is the adoption process of educational data applications and analytics, with several issues requiring attention in the incorporation of learning analytics in higher education. Academics' lack of readiness and concerns about data ownership, privacy, and stakeholder involvement are significant barriers (Howell et al., 2017; Wong et al., 2018). Moreover, the challenges arise from the socio-technical nature of learning analytics and the complexities associated with the adoption of innovations in higher education institutions (Gašević et al., 2019). Organizational factors, including institutional structures, commitment, resources, readiness, capacity, and the absence of incentives and rewards, create barriers to the implementation and adoption of learning analytics (Lester et al., 2017). Furthermore, ethical concerns related to educational data ethics are considered hindering factors in the application of learning analytics in higher education (Guan et al., 2023). The challenges of ethics and privacy in analytics and educational data applications within higher education are multifaceted, encompassing legal, technological, and ethical dimensions. Addressing these challenges requires a comprehensive approach that considers legislative initiatives, technological design, and the perspectives of students and other stakeholders. These potential barriers need to be considered if there is a desire to expand and utilize big data applications and create analytics policies in Turkish higher education.

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CHAPTER

# Artificial Intelligence Form of Digitalized Communication: ChatGPT

6

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## Introduction

Today, Artificial Intelligence (AI), which is a source of inspiration for scientists doing research in many different fields, is rapidly advancing and developing with the contribution of information technologies. AI manifests itself in many areas of life and research. This technology is constantly developing and improving with advances in the field of informatics. Users of artificial intelligence technologies can do many routine and time-consuming tasks more easily and quickly, saving time.

As computer and information communication technologies continue to develop over the years, the way for the development of artificial intelligence has been paved. AI is the ability of machines to adapt to new situations, solve problems, answer questions, plan, and perform a variety of other functions that require a certain level of intelligence in humans. Artificial intelligence from another perspective; it is defined as the study of intelligence behavior in humans and machines and trying to turn such behavior into an output such as computers and computer-related technologies. The reason why various definitions of the concept of artificial intelligence are used is that this concept can be applied in many different fields such as psychology, engineering, sociology and health. Therefore, the term artificial intelligence can mean different things when considered from different perspectives (Doğan, 2002). Based on these definitions, it is stated that artificial intelligence is the culmination of innovations and developments in information and communication technology and is the main feature of software that tries to imitate the human brain and has intelligence in the context of human intelligence (Coppin, 2004;

Whitby, 2008; Chen, Chen and Lin, 2020).ChatGPT (Artificial Intelligence -supported chat robot), one of the most important examples of artificial intelligence technologies in recent times, has influenced many fields of work, especially content creation and education processes, due to its potential in terms of data production (Bostrom, 2014). ChatGPT , an AI application , is an AI chatbot developed by OpenAI (US -based AI research company) and released in November 2022. This application is built on basic large language models and fine-tuned using both supervised and reinforcement learning techniques (ChatGPT, 2023). ChatGPT application has managed to attract great attention in a short time due to its ability to provide humanoid responses. ChatGPT differs from other artificial intelligence applications because it brings a new breath to digital communication and is significantly superior to its existing counterparts.

Although artificial intelligence discussions have a long history, studies on ChatGPT are still a very new issue. Although new studies on this application have emerged recently, studies in the context of artificial intelligence and ChatGPT are quite limited. Considering the recent studies on the basis of ChatGPT; It has been observed that different branches of science focus on its impact on health, economy and other sectors (Atlas, 2023; Biswas, 2023; Crawford, Cowling and Allen, 2023; Lo, 2023; McGee, 2023). In our country, studies based on artificial intelligence and ChatGPT are not yet at a sufficient level. However, it has been observed that the studies carried out are generally on education, economy, tourism, security and software technologies (Yiğit, Berşe and Dirgar, 2023; Bilge, 2023; Özevin, 2023; Keskin, 2023; Küçüker, 2023). This study was carried out to understand the potential and features of ChatGPT, the latest popular artificial intelligence technology. Thanks to this study, the depth of this application, which has a very clear future, will shed light on future studies.

## Artificial intelligence

Change and digitalization processes that occur due to technological developments continue to progress unstoppably, and this process, called the digital era, continues its transformation in stages.

As a result of developing information technologies, the internet evolved and first appeared as Web 1.0. While Web 1.0 represents the first-generation internet and allows one-sided communication and content production, with Web 2.0, the size of this communication has increased and become an indispensable part of people's lives. With Web 3.0, an attempt has been made to transform it into a decentralized form, eliminating the need for intermediaries for communication. The intermediaries in Web 1.0 are servers, and the servers needed to interact with someone were replaced by platforms in Web 2.0, and communication began to be established by registering. Web 3.0 will allow establishing a decentralized connection without any intermediary in the coming years, thanks to the improvements made on it (Arvas, 2022; Koçak, 2023). The characteristics of the development processes of web technologies are shown in Table 1.

**Table 1.** *Features of Web 1.0, Web 2.0 and Web 3.0 (Grayscale Research, 2021)*

| | **Web 1.0** | **Web 2.0** | **Web 3.0** |
|---|---|---|---|
| Interaction | Read | Reading-Writing | Reading-Writing-Possession |
| Vehicle | Static Text | Interactive Content | Virtual Economies |
| Organization | Companies | Platforms | networks |
| Control | decentralized | Central | decentralized |

The concept of artificial intelligence was first used at the Dartmouth Conference in 1955, and its definition has been continuously worked on since then. Prof. John McCarthy, who used the concept of artificial intelligence for the first time at the conference, stated that artificial intelligence is machines that can think like humans, make decisions, perform tasks that humans focus on, and solve problems. However, today, the definition of artificial intelligence is not limited to this comprehensive definition, but is addressed more comprehensively and from different perspectives (Elmas, 2018). Definitions of AI in important and different sources are given in Table 2.

**Table 2.** *Prominent definitions regarding Artificial Intelligence*

| Researcher | Year | Definition |
|---|---|---|
| Bellman | 1978 | Automation of activities that we associate with Human Thought…. Activities such as decision making, problem solving, learning |
| Haugeland | 1989 | Exciting new effort to make computers think… literally mental machines |
| Kurzweil | 1990 | The art of creating machines that perform functions that require intelligence when performed by humans |
| Schalkoff | 1990 | A field of study that seeks to explain and mimic intelligent behavior in terms of computational processes |
| Rich and Knight | 1991 | Study of how computers can do things they are better at than humans |
| Winston | 1992 | The study of computations that enable perception, reasoning, and action |

## Types of Artificial Intelligence

When current and future artificial intelligence systems are examined, it is observed that artificial intelligence is classified into four different groups (Mijwil and Abttan, 2021).

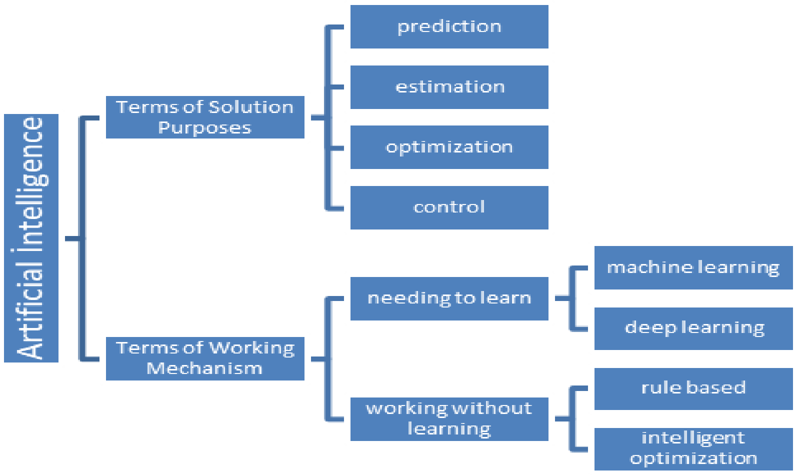
a) *Reactive Machines:* IBM's Deep Blue chess program defeating world champion Kasparov in 1990 is cited as the best example of reactive machines. But deep Since Blue had no memory, past experiences could not be used for future activities.
b) *Limited Memory:* These are systems that make their decisions by taking advantage of past experiences. It has been observed that such systems are used more frequently in vehicles.
c) *Theory of Mind:* This theory is essentially a psychological concept. Recognizes that others have beliefs, desires, and intentions that influence their decisions.
d) *Personal Knowledge:* This type will have a thought and consciousness of its own. Such artificial intelligence systems use information obtained by making inferences about current situations to understand the emotions of others.

## Classification of Artificial Intelligence

At the core of artificial intelligence is problem solving. Therefore, it is very difficult to put the techniques, algorithms and applications in order. However, it is still possible to make a classification when considered from different perspectives (Ginsberg, 2012; Melin et al., 2017). Artificial intelligence is divided into certain classifications in terms of its working mechanism and solution purposes, as seen in Figure 1 (Köse, 2021). In this context, there are certain capabilities that computer systems must have in terms of artificial intelligence. These abilities are as follows (Küçüker, 2023):

- Natural Language Processing Capability
- Information Display Presentation Ability
- Automatic Reasoning Ability
- Machine Learning Capability

**Figure 1.** *Classification of Artificial Intelligence (Köse, 2021)*




## Technologies Using Artificial Intelligence and Expectations

When the technologies using artificial intelligence are examined; "Artificial Neural Networks, 3D Printers, Augmented Reality, Block Chain, Cloud Computing, Big Data, Deep Learning, Industry 4.0, Industrial Robot Technologies, Machine Learning, Internet of Things, Autonomous Robots, Virtual Reality, Cyber Security, Society 5.0" (Loijens et al., 2017; Mendi, 2021; Kösebay, 2020; Badaoui et al., 2017; Myers et al., 2020; Sivathanu and Pillai, 2018; Alpaydın, 2011).

Artificial intelligence is used in many different sectors today, and its areas of use will gradually increase in the future. Future predictions about the use of artificial intelligence in different sectors and under different technologies are as follows;

1. Health: Artificial intelligence can be used in the field of health for diagnosis, treatment and prevention of diseases. Artificial intelligence algorithms can analyze medical data to provide early diagnosis of diseases, create treatment plans and be used for drug discovery.
2. Education: Artificial intelligence can be used to enhance students' learning experiences. Artificial intelligence can provide customized educational materials by analyzing students' learning styles, interests, and strengths.
3. Finance: Artificial intelligence can be used in many areas in the financial sector, such as fraud detection, credit risk assessment, investment strategies and portfolio management.
4. Law: Artificial intelligence can also be used in the field of law. Artificial intelligence can be used in many areas such as making court decisions, analyzing legal documents and contract management.
5. Transportation: Artificial intelligence can be used in the development of autonomous vehicles of automobile manufacturers. It can also be used for traffic management, driverless public transportation systems and security systems.
6. Art: Artificial intelligence algorithms can be used in many areas such as creating paintings, music and videos.

These predictions mean that AI technology will be used in almost every industry, and as the number and diversity of AI applications increases, AI technology will also become more advanced.

## Natural Language Processing and CHATGPT

Studies in the field of Natural Language Processing and Deep Learning are aimed at understanding the structure of language, modeling language learning processes, and understanding machine language similar to human language. Natural language processing is a set of theoretically motivated computational techniques for analyzing and representing naturally occurring texts at one or more levels of linguistic analysis in order to achieve human-like language processing for a range of tasks or applications (Liddy, 2001). Many Natural Language Processing (NLP) applications are used in areas such as vocabulary creation, semantic analysis, syntax analysis, sentiment analysis and machine translation. It is also used in many industrial applications such as natural language processing, voice assistants, digital advertising, social media analytics and customer service.

Recently, advances in deep learning and natural language processing have enabled a great progress in the development of language models. In particular, large language models such as Google's BERT, OpenAI's GPT, and Facebook's RoBERTa have achieved great success in various NLP applications. In addition to these applications, applications such as Chatsonic, JasperChat , YouChat , Character AI and Pi also use ChatGPT- like features.

Much of the research in the field of natural language processing is conducted using machine learning techniques. Therefore, machine learning steps such as data collection, data pre-processing, model training and evaluation of results play an important role in the development of NLP applications (Adalı, 2012).

### ChatGPT

ChatGPT, first released as a prototype on November 30, 2022, is a chatbot developed by OpenAI. There are ChatGPT, GPT-3.5 and GPT 4.0 versions, which basically act as virtual assistants (Khan et al., 2023).

ChatGPT; It is an artificial intelligence-based chatbot written in Python language, developed by OpenAI. The robot can answer the questions asked to it as if it were a human. In addition, ChatGPT can understand what language you write in, create descriptive texts and content, write programs in different programming languages and debug them (Krupiy, 2020).

### ChatGPT Working Principle

This tool, which works like the human brain, uses interconnected neurons and learns from the data it obtains and predicts the subsequent process (answers).

- Artificial Intelligence educators have taken into account the Reinforcement Learning from Human Feedback (RLHF) model in developing the response system for the artificial intelligence process.
- ChatGPT works on the RLHF model. Thanks to this model, it collects data in a slightly different way compared to other alternatives.
- The ChatGPT database has been merged with data from the previous system, InstructGPT. The combined data was converted into a dialogue form.
- The data compared is collected from two or more sample responses sorted by quality.
- The information is obtained from the conversations that Artificial Intelligence instructors have with the chatbot.

## ChatGPT Features

ChatGPT can interact with people using natural language, answer the user's questions or produce texts as part of the conversation using natural language processing techniques. ChatGPT further increases the use of artificial intelligence technology in interacting with people (Salvagno, Taccone, & Gerli, 2023)

ChatGPT, whose most well-known feature is " question-answer", are as follows:

*Text Writing:* Thanks to ChatGPT, you can write academic articles, literary texts, movie
scripts, etc. All text- based content can be created.

*Mathematical Equation Solution*: ChatGPT has the ability to solve difficult equations in seconds. It can even explain the solution methods of equations in the most understandable way.

*Interlingual Translation*: The application, which translates between all languages, also
contributes to your foreign language development by chatting with you from the simplest level to the most challenging level.

*Classification*: Information on any subject can be categorized and classified more quickly thanks to ChatGPT.

*Giving Advice*: When you ask questions about a topic or activity, they can give you advice about it.

*Debugging*: With ChatGPT, which is very successful in writing and developing code, you can learn about errors in a code block and these errors can be easily edited.

## Advantages and Disadvantages of ChatGPT

ChatGPT offers different advantages to users. However, in addition to its advantages, it also brings certain disadvantages in terms of communicative processes. These evaluations vary depending on certain characteristics such as intention to use and line of business. Therefore, ChatGPT can offer answers and opportunities as well as negativity to the sector or person according to their wishes ( Salvagno , Taccone and Gerli , 2023; Lu etc., 2018).

Advantage of Chat GPT:

- Fast and Easy Communication
- Broad Subject Coverage
- Personalized Service
- Error Correction Capability
- Chat Based Communication
- Content Creation
- Sensitivity Analysis
- Data collecting
- Customer Service Automation

Disadvantages of Chat GPT:

- Lack of Empathy
- Bias and Accuracy Issues
- Limited Context Awareness
- Scaling Challenge
- Need for Human Oversight

## Discussion

Considering that the evolution of artificial intelligence developed by humans has gone through a process similar to human learning, it remains unclear what it will turn into in the future, how independent it will be in the decision-making phase, and how its harmony with humans will be shaped. As a result, emerging artificial intelligence applications may bear characteristics of the people who program them.

ChatGPT, a successful artificial intelligence technology, is a natural language processing model developed by OpenAI company. ChatGPT is a technology that can summarize or write about any topic written in natural language.
There are certain reservations because the program reaches the questions and requested information in digital environments and makes it available without citing sources. Also, marketing, education, healthcare, etc. Since it has started to be used in many other areas, it has the potential to mislead individuals.

ChatGPT, ensuring the accuracy and reliability of the information obtained is a significant challenge. Even though ChatGPT is planned through a serious data source, there is often the possibility of errors or oversights during the training process. Therefore, it would not be wrong to say that, in addition to the benefits of the program, it also brings with its certain ethical concerns.

ChatGPT, in fact, the most important limitation of artificial intelligence is that it requires more emotional intelligence. In human communication, it can be difficult to understand and respond to emotional cues such as humor or comedy. Therefore, people may find it difficult to communicate successfully and effectively with chatbots and automated systems (Kalla, D. & Smith, N. 2023). ChatGPT will change the communicative habits of both individuals and institutions among all these positive and negative discussions.

## Conclusion

ChatGPT, an artificial intelligence chat robot specialized in dialogue developed by OpenAl company, is an artificial intelligence product that enables users to make transactions without the need for human power by shortening their computing processes. ChatGPT is considered as the interaction between artificial intelligence and humans.

ChatGPT usage offers significant developments and opportunities. This technology can become an effective tool in research and applications by further increasing the quality and accessibility of various services. ChatGPT's ability to quickly generate consistent responses makes it useful for digital communications that require high volumes of communication, such as answering customer inquiries or conducting surveys. With ChatGPT, businesses can automate certain communication tasks, which can help reduce workload and allow staff to focus on other tasks. However, in the coming periods, it may be necessary to provide more data to improve ChatGPT and other artificial intelligence models and obtain more effective results.

Artificial intelligence technologies can benefit humanity in aspects such as workforce, research and detection. However, it is not currently possible for artificial intelligence technology to fully replace human ability and knowledge. It should also be noted that although it is used as an active support program in many areas, especially considering its deficiencies in issues such as producing false information, lack of emotional intelligence, security and ethics, it has not yet replaced humans.

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CHAPTER

# Technology and Innovation Management in Times of Crisis: Problems and Suggestions

7

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## Introduction

Today, obtaining, using, sharing, and managing information with the formation of information societies is preferred as a management strategy. Technology is used effectively in this process. It is very important to use the technology resources effectively and efficiently and to create value for society. Important points of management can be determined easily with effective and efficient technology management. Technology management has made serious progress in the technological and industrial transformation process defined as industrial revolutions. It is observed that as the effects of technology on the industry develop and the efficiency of the resources increases, the authority and management skills of technological factors also develop (Davutoglu 2019). Because technology provides new facilities and opportunities to societies. Institutions or organizations can perform their duties more easily in cooperation with each other by using technology, and accessing all kinds of information they need faster. However, an important point here is to use the right technologies at the right time and sufficiently. Thus, the technologies used will be a labor force for societies and the competitiveness of institutions will be created (Dusukcan and Kaya 2003).

Technological changes occur in line with the needs of the development of technology. These changes affect societies according to their level of development and welfare. It is necessary to monitor the technologies used, anticipate the technological changes, and adapt to these changes in order to be affected by this situation at the minimum level in the negative sense and at the maximum level in the positive sense. They both lose their competitive power and cannot make the right decisions for their future when businesses providing information and service production cannot adapt to technological innovations or changes. In addition, they may face serious economic and strategic difficulties. Businesses can prevent damages that may come to them, and realize their production and investments more accurately with effective and timely technology management. Therefore, institutions need effective technology and innovation management when considering the rapid development of technology (Karadal and Turk 2008).

The concept of technology management can be expressed as the planning, development, and implementation of technology for businesses to achieve their operational and strategic goals. This subject can be thought of as integrating engineering and management science disciplines. It is thought that technology management provides competition for businesses and is effective in creating value. According to the size of the businesses, technological management should ensure that the entire technological infrastructure is compatible with the needs of the institution or personnel (Kaya et al. 2017). Because societies may face certain risks or threats in their daily life and business life. Some of these risks and threats can cause a low negative impact and some of their an irreversible impact. Normally, risks with low realization potential have a high negative impact. The best example of this is infectious diseases, that is, global epidemics that have spread around the world. Global epidemics have various characteristics, spread rapidly to very large masses, and cause fatal consequences, especially for human health. Therefore, at this point, businesses should closely follow technological developments, especially in crisis periods to overcome the encountered risks with minimum damage and apply the necessary technology and innovation management processes effectively (Karli and Tanyas 2020, Deloitte 2020). In this context, it was presented the importance of technology and innovation management in crisis periods, approaches in technology management, tools used in technology management, the problems encountered in the technology management process, and measures that can be taken against these problems in the study. In the second part of the study, it was explained the technology, innovation, technology management, and innovation management concepts. In the third, it included technology and innovation management in times of crisis and the problems encountered and suggestions in this process, and finally, in the fourth part, the conclusion and recommendations part of the study.

## Technology and Innovation Management

Technology and innovation management is both a technical field and a discipline. In this section, there are important subheadings about technology and innovation management. It is seen that there are different definitions and approaches to technology and innovation management when the literature is scanned (Arciénaga Morales et al. 2018). In Table 1, these approaches are summarized.

**Table 1.** *Approaches to technology and innovation management*

| Reference | Proposal |
|---|---|
| (Dogson et al. 2000) | New product development<br>R&D management<br>Technology strategy<br>Commercialization<br>Technological collaboration<br>Operations/Production<br>Organizational learning<br>Creativity<br>Complexity<br>Risks |
| (Tidd et al. 2005) | Strategic approach<br>Strategic learning<br>Setting effective external linkages<br>Managing internal process<br>Creating innovative new firms |
| (Adams et al. 2006) | Management of inputs<br>Knowledge management<br>Innovation strategy<br>Organizational culture and structure<br>Portfolio management<br>Project management commercialization |
| (Shane and Scott 2008) | Development and introduction of new products<br>Management and organization of innovation<br>R&D project selection<br>Portfolio management<br>Technology and innovation strategy<br>Intellectual property and innovation<br>Technology-based entrepreneurship<br>Financing of innovation |
| (Lopes et al 2012) | Organizational strategy<br>Project management<br>Knowledge management<br>Product management<br>Types of innovation<br>Technological innovation<br>Open innovation |

## Technology

Technology is defined as a knowledge field formed by the research of construction techniques and tools related to an industrial field, an application carried out to obtain a commercial value, an element that determines the life levels of societies or the planning, development, and application of the technology that needed to create and achieve the strategic goals of an organization (Ince et al. 2004).

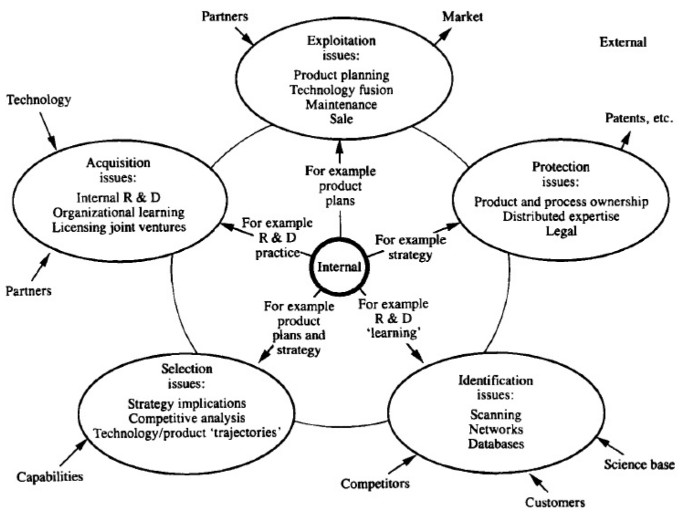
Technology is a physical product that generates information and value, and a non-physical service or output. The type and size of technology change and evolve with the change of personal or corporate needs. In addition, technology contributes to a faster and higher quality product at a lower cost. Technology is an important resource for everyone and provides a competitive advantage, especially for businesses (Cakmak et al. 2012).

Today, the concept of technology is widely used. However, this concept can still be perceived in different definitions. Some scientists define technology as physical hardware, while others consider it theoretical (software). Physical hardware includes technological devices. In the theoretical sense, it covers learning techniques or management styles according to the area where technology is used. The physical dimension of technology can be defined as a tool like robots. However, effective use of robots is possible with programming knowledge. Therefore, this situation reveals the theoretical dimension of technology. The concept of technology can also be classified as product or process technology. Product technology is the activity carried out for the development of new products or services. Process technology is the technology developed to realize the production process. Developments in process technology contribute to the development of production technology by enabling the development of more qualified products (Karadal and Turk 2008).

## Technology management

New technologies can be used to survive in a competitive environment and to produce products on time, with quality, and at an affordable price. This situation leads organizations to develop new investments and strategies. Therefore, at this point, the need arises to provide and manage the technology obtained and used (Cakmak et al. 2012). Technology management includes the development, implementation, planning, control, and coordination of technological tools to determine the strategic and operational goals of enterprises and to achieve these goals (Tekin and Goral 2010). The concept of technology management includes the concepts of product and process development, the strategies of businesses, product development activities, process renewal, and development methods, technology transfer, change management, and technological change (Ince et al. 2004). In short, the technology management process consists of *determining, selecting, acquiring, using,* and *protecting* technology (Gregory 1995). Fig. 1 shows Gregory's technology management process.

**Figure 1.** *Technology management process (Gregory 1995).*




In summary, technology management aims to answer the following questions:

- How are technology policies and strategies developed?
- How to benefit from existing technologies?
- How to keep track of market and technology changes to ensure a competitive

edge?

- How is technology produced?
- How is technology protected?
- How to buy new technologies?
- How are technologies that will contribute to business processes evaluated and selected?
- How is technology transferred?
- How are technology producers managed?
- How are technology assets integrated and used effectively?

Technology management provides guidance on issues such as the combination of management and technique, the determining technology and investment method for businesses to compete, the way technology is produced, developed, and marketed, how the organizational structure is changed according to new technological developments, and the competitive strategy to follow with current technology (Yildiz, 2007).

In general, it is possible to categorize the activities of technology management under 9 main headings as follows (Yildiz, 2007):

- Technology strategy,
- Technology planning and forecasting,
- Technology creation / R&D management,
- Technology measurement and evaluation,
- Technology transfer,
- Technology integration,
- Use of technology,
- Commercialization and marketing of technology,
- Technology organization/knowledge management.

### *Approaches in Technology Management Process*

In the technology management process, there are two approaches micro and macro. The micro approach involves planning, coordinating, and directing technology on a company basis. The macro approach which other approach covers all activities related to technological forecasting, technological planning, determination, implementation, and control of science-technology policy throughout the country. The purpose of technology management based on companies is to increase the profit and production of the enterprise to the targeted point by planning, organizing, and coordinating the human resources at the optimum level. Technology management covers the following topics (Kurtulan 2009, Akkoyun 2016):

- Technological Prediction
- Technological Planning
- R&D Management

- Technology Transfer
- Technology Selection

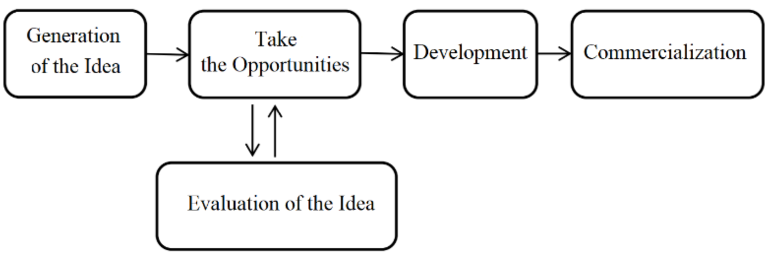
### *Tools Used in Technology Management*

Technology management can benefit from many tools, methods, and techniques while performing business processes. Although many of these tools are developed in different disciplines such as strategic management, information management, and total quality management, they can also be considered within the scope of technology management activities. In addition, these tools can be classified under two main headings "Definition" and "Benchmarking" tools. The Technology Identification action is an action that covers the process of defining critical technologies for the company by identifying the technologies that are being developed or available, collecting, analyzing, and evaluating the information on these technologies. Benchmarking is a method that enables the firm to measure its own strategies and performance by comparing them with the "best ones" (Cakmak 2012).

## Innovation

The concept of innovation is the state of making changes in the structures, strategies, management processes, and administrative affairs of businesses. It is the application of a new product, idea, service, or process in the business processes of the business. In addition, innovation refers to the change in different business processes and services. It is the process of generating ideas and designing technology for a product that has never been applied before. Innovation, which includes commercialization, is an organizational process from the creation of the idea to economic income. It reveals new ideas for solving any problem and implements these ideas in the market. Innovation is the transformation of an idea or knowledge into economic and social benefits in any field. Innovation is the abstract and general design of an object, an emotion, or a thought in the mind, an invention, the introduction of a new situation, and the use of new information possessed by technology and the market. It is not just an activity, but a thought that emerges as a result of its sub-stages and their interaction with each other (Aydin and Bekmezci 2020). Innovation deals with finding a new management approach, commercialization, and information processing methods, and applying them. It is a tool for entrepreneurship. It enables new ideas to be transferred to a marketable product or service in the market. Innovation is actually a renewal process that businesses or organizations experience in order to adapt to environmental changes (Gursel 2017). In Fig. 2, the steps of the innovation process are given.

**Figure 2.** *Innovation process (Luecke 2011)*




Innovation has social and organizational dimensions. The social aspect of innovation is to increase the quality of life and welfare of society, and its organizational aspect is that competition has a process, and it provides integration into the problem-solving process (Bakir 2016).

## Innovation management

Innovation management plays an active role in providing companies with a sustainable competitive advantage and has a strategic understanding. A data source is required for this understanding to begin and apply. It is possible for businesses to use these resources effectively by developing and managing innovative ideas, services, or products. Innovation management, which provides a sustainable competitive advantage to businesses, is a strategic management approach that should be applied not only in the moment of need but also continuously. Internal and external information sources are required for the initiation and continuity of the innovation management process. R&D studies are required to ensure the continuity of information. In this context, it comes to the fore the need for innovation in innovation management and the steps of generating, developing, and commercializing new ideas. The need for innovation arises as a result of the business feeling obliged to innovate by taking customer needs into account. In addition, businesses may have to innovate due to their own internal dynamics. This need for innovation can be related to products and services, as well as methods and techniques, organizational structure, and processes. The innovation process is a process that starts with the creation of new opportunities, in other words, with the opportunity to think creatively. At the stage of the development of the idea of innovation, the planned innovation becomes a physical product or process, since the idea of innovation ceases to be an idea and turns into reality. The next step is to test the resulting sample and make the necessary corrections and improvements. Products and services whose market research is completed are produced in large quantities and placed on the market. The promotion of renewed products and services in the market is provided by sales development and advertising activities (Gursel 2017).

Innovation management activities are divided into four categories:

- *technical integration* that integrates technology and markets to meet customer demands,
- *the innovation process* in which interdepartmental cooperation and cross-functional activities are effective,
- *strategic technology planning* where projects for technology or competence development are envisaged,
- *the business development process* in which innovation by the organizational change is developed, or that is developed by innovations.

In summary, innovation management includes the elements of creating an innovation strategy, generating new ideas, prioritizing and selecting ideas, implementing selected ideas, and involving employees in the whole process (Ventura and Soyuer 2016, Goffin and Rick 2005, Drejer, 2002).

## Technology and Innovation Management and Problems Encountered in Times of Crisis

Businesses and societies have to develop new strategies in the face of technological change. However, this process takes place in a troublesome and difficult way because there are too many variables and constraints. Especially in times of crisis, these processes create more problems. Therefore, it should be determined in advance threats, risks, and problems that may be encountered in technology and innovation management applied in crisis periods, and necessary interventions should be made at an early stage. For example, businesses established for commercial purposes need to consider the customer and the industry in order to provide quality products or services. This is only possible with an effective technology and innovation management approach. A technology developed at an unexpected moment will cause the habits of the past to be seriously changed. At this point, it is important for the culture of being ready for technology and innovation and adopting this issue. Developing firm strategies in the face of technological change means that managers take into account many variables and constraints and identify risks. Sudden and revolutionary technological innovations are new products and services that significantly change the old habits of the customer and the market. The result of changing behaviors and habits is to benefit greatly from technological innovation (Cakmak 2012).

Businesses experience also some problems in this process, as in other management processes since technology and innovation management is a very broad concept and an interdisciplinary subject. It is possible to list these problems as follows (Calp and Dogan 2015):

- Lack of knowledge
- Lack of resources
- Use of important resources in different projects
- Experiencing disciplinary problems
- Managers not taking responsibility when making particularly difficult decisions
- Weak cooperation culture in institutions
- Incompatibility between staff
- Experiencing cultural differences
- Experiencing ideological or differences of opinion
- Communication problems
- Problems in the technology supply

There are some difficulties in innovation management, such as not being able to determine how innovation is formed or developed, the way of organizing for innovation, and how the innovation will interact with the organization. The reason for these difficulties is that innovation is a subject that focuses on fixed products and has defined boundaries, failure to centralize the innovation organization and the innovation processes consist of different subjects (Nambisan et al. 2017).

The production must understand the product requirements, the products are producible, and the appropriate and skilled process technologies are provided to overcome these challenges. In this context, product richness is a possible strategy to increase the competitiveness of an organization. However, all companies have not effectively involved their production staff or modified their manufacturing practices to support process and product innovation. Some researchers have associated this imprecise or variable outcome model with the impact of unexpected factors such as plant size, type of production process, work organization methods, and competitive strategy (Arana-Solares et al. 2019).

In general, the problems encountered in technology and innovation management are grouped under the main headings below, and the contents of each are given in items (Cakmak 2012).

a) Problems Experienced in Technology Identification and Selection Step

b) Problems Encountered in the Technology Planning Step

c) Problems During Stakeholder Meetings

d) Problems During the Application of Technology Transfer

e) Problems Emerging from Insufficient Abilities (Human and Financial)

f) Problems Emerging from Ineffective Management

**a) Problems Experienced in Technology Identification and Selection Step**

- Wrong technology choice
- Inability to meet the needs due to the incompatibility of the determined technology with the infrastructure
- Perceiving the complexity of the specified technology by the customer or the user

**b) Problems Encountered in the Technology Planning Step**

- Not serving the user's needs
- Not taking part in the planning process
- Being indifferent to the technology to be acquired
- Being indifferent to the information, product or service to be obtained
- Exaggeration of technological capabilities
- Incorrect estimation of printouts
- Transferring technology by the wrong means

**c) Problems during Stakeholder Meetings**

- Educational and cultural differences on both sides
- Differences in approach and strategy during the interviews
- Distrust among stakeholders
- Inconsistency in goals and objectives
- Conflict in pricing and marketing strategies
- Unrealistic time constraints to reach the goal

**d) Problems during the Application of Technology Transfer**

- Lack of experience of managers
- Obtaining technology-related documents incomplete
- Lack of achieving quality targets
- Lack of coordination in accessing materials for technology use
- Low quality and high cost of the materials reached
- Whether technology is monitored effectively or not

**e) Problems Emerging from Insufficient Abilities (Human and Financial)**

- The client's lack of experience and skills

- Lack of knowledge of the personnel involved in the process
- Not being open to new systems
- Lack of skills for technology internalization
- Communication problems between stakeholders
- Lack of report request

**f) Problems Emerging from Ineffective Management**

- Lack of support in management
- Inadequacy of senior management in intermediary role in all steps related to technology
- Errors, inadequacies, and differences in working methods
- Inadequacy in inputting current technologies into a competitive environment
- Inability of management to recognize and authorize staff with whom it works

Businesses that consider all these problems should understand product requirements, manufactural products, and provide skilled processing technologies to bring products to market faster and more cost-effectively. At this point, products and services wealth should be provided, especially in order not to be adversely affected by crisis periods. Because product and service wealth is a possible strategy to increase an organization's competitiveness. However, companies cannot effectively utilize production personnel or change their production practices to support process and product innovation (Arana-Solares et al. 2019).

## Conclusions and Recommendations

In the study, they were presented a detailed analysis was made about technology and innovation management in crisis periods, management processes and the problems encountered in this process, and some suggestions. The results of the analysis showed that the rapid change and development experienced in technology significantly affect the business processes of enterprises. In addition, it must be carried out effectively and completely in the processes of defining, identifying, obtaining, and protecting technology (technology management). This issue is much more important, especially in times of crisis. The more effective and careful technology and innovation management are carried out in times of crisis, the more at the requested time, the desired amount, lower cost, and better quality of businesses can produce their products. In addition, enterprises can accurately predict the developments in the field of technology with an effective technology and innovation management approach and thus plan their investments and production according to the data they have. The important point here is that it should organize in cooperation, brainstorm periodically, and adjust time management well for successful technology and innovation management, the people in the technological planning team.

It becomes important the manageability of the technology and new product and innovation processes areas, in which the production and service sectors concentrate their interests. The rapid change in technology pushes companies to combine some of their capabilities with some of their outsourcing capabilities. Therefore, enterprises should be more open to advanced production technologies and should be able to use these technologies by adapting them to their organizations. The transfer and operation of production management technologies should be carried out with good planning, taking into account the conditions of the organization. Human resources should be harmonized with the necessary technical equipment. On the other hand, business managers also have great responsibilities. All kinds of processes related to technology fall under their responsibility. The realization of the technology management process with the most efficient results, open to improvement and innovation, and with a participatory understanding will reflect positively on the balance sheet of the enterprises. Because the capability of the technology manager comes to the fore in this process, and therefore business managers have great responsibilities in this regard.

In addition, businesses should not be afraid of using advanced and new technologies, and they should be more aggressive in technology transfer and use. Technology and innovation management organizes the group and ensures that the work is done more effectively, productively, and widely. Technology management activities must take place in light of the results and suggestions mentioned above, in terms of being affected at a minimum level by possible adverse situations.

In light of all this, more scientific research should be done to reveal the difficulties or problems encountered in the process. It should be different technology and innovation management approaches developed to overcome all problems, especially in times of crisis. In addition, a system can be developed to organize, manage, analyze, and monitor technology and innovation management activities in a more dynamic and applicable manner. Finally, technology and innovation management should not only be adopted by individuals and institutions, but also countries should include this issue in their domestic policies.

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CHAPTER

# Determining the Criteria for Choosing a Cloud Computing Provider in the Public Sector

8

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## Introduction

Cloud computing is an internet-based service model that includes various technological resources, hardware, software, networks, and storage. This model enables users to easily access information technology services over the Internet whenever they need them. These services include server, storage, database, network, software, analytics, and other services. Cloud computing helps businesses to provide more efficient, flexible, and cost-effective services, especially by facilitating businesses' challenging operations such as big data processing, storage, and sharing (Mell & Grance, 2011).

The public sector, like other sectors, is turning to technological innovations to optimize business processes, reduce costs and improve service quality. One of these innovations is cloud computing. Cloud computing provides flexibility, scalability, and cost savings to businesses and organizations by making it possible to access computing resources from anywhere and at any time via the Internet. In the public sector, cloud computing services are used for big data management, collaboration, communication, and service delivery. However, public sector organizations have to consider several factors when choosing a cloud computing provider. Security, data privacy, compliance, pricing, and performance are the most important of these factors. Public sector organizations should correctly identify and evaluate these criteria and choose the right cloud computing provider for the continuity of their business processes.

Cloud computing providers offer different service models, especially customized services for the public sector. However, choosing the right service model and identifying the right provider will benefit businesses. To make the right choice, public sector organizations should consider issues such as the provider's performance, security features, pricing policies, management, data backup, and recovery. Therefore, the decision to choose the right provider is of great importance for the success and future of your organization's IT systems.

The aim of the reserach is to identify the criteria that should be considered when selecting a cloud computing provider in the public sector. This study can serve as a guide to help public sector organizations choose the right cloud computing provider.

The paper is organized as follows: In the second section, cloud computing services will be defined and the use of cloud computing in the public sector will be analyzed. In addition, this section briefly explains the Analytic Hierarchy Process (AHP) proposed by Saaty (Saaty, 1980) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) proposed by Hwang and Yoon (Hwang & Yoon 1981) used in this study from multi-criteria decision-making techniques. In the third section, the studies in the literature on cloud computing service provider selection and MCDM methods in the public sector are analyzed. In the fourth section, the stages carried out through the sample application are explained and the criteria are weighted with the AHP approach and the selection of the most appropriate criterion among the alternatives is carried out with AHP and TOPSIS methods. In addition, the steps of the TOPSIS method are given in detail as an example of the calculations applied in this section. Finally, the results of the study and recommendations are presented.

## Cloud Computing Services

### Definition and Characteristics

Cloud computing services encompass a range of technological resources, hardware, software, networks, and storage that are delivered over the Internet. These services can be used to meet the IT needs of a business and can be customized according to the needs of businesses. Cloud computing services offer a flexible subscription model based on the services that users need for their business. In this way, businesses can get scalable, customizable, and cost-effective services by their business needs. Cloud computing services are typically offered through three different service models: software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS) (Mell & Grance, 2011).

Cloud computing services are offered by a range of providers that deliver IT services to businesses over the internet. These services enable businesses to access big data processing, storage, analysis, application development, database management and other services. Businesses can easily sign up for cloud computing services and payment is based on a charging model, usually based on the amount of usage or the length of the subscription. Cloud computing services help businesses save time and resources and provide a fast and scalable service (Ambrust et al., 2011).

Cloud computing services provide a flexible, scalable, fast, and cost-effective service. The features of these services make it easy for businesses to scale quickly, access IT resources, and manage their services. Cloud computing services reduce costs and improve business continuity by providing services such as data center management, security, backup, and recovery. Cloud computing services enable businesses to provide fast, uninterrupted, and high-performance services to their users around the world. Cloud computing services help businesses save time, resources and costs while enabling them to innovate faster. The features of cloud computing services have revolutionized the way businesses deliver IT services and have changed traditional IT management models (Vaquero et al., 2014).

Cloud computing services are an essential technology to adapt to today's rapidly changing business world. These services help businesses become faster, more flexible, and more efficient. Cloud computing services provide a huge advantage, especially for small and medium-sized businesses. These businesses can easily access IT services that were previously inaccessible to them due to high costs. Cloud computing services help businesses on their digital transformation journey, while at the same time reducing their costs and enabling greater efficiency (Duan et al., 2015).

## Types of Services

Cloud computing services consist of many different types of services. These services can be customized according to the needs and budgets of businesses. By using cloud computing services, businesses can optimize their business processes, increase their efficiency, and reduce their costs. In addition, cloud computing services can be used for data storage, data analysis, software development, network management, and more. The most popular types of cloud computing services are:

- **Software Services (SaaS):** This type of service allows users to access software applications over the internet. In this type of service, users do not have to download and install the software on their computers. Instead, software providers host the software on their servers and users access it over the internet.
- **Infrastructure as a Service (IaaS):** This type of service gives users access to basic IT infrastructure resources such as virtual servers, storage and network components. Users can customize and manage these resources according to their needs. This type of service allows businesses to utilize infrastructure resources provided by the cloud provider, rather than purchasing and managing their infrastructure (Bhardwaj, et al., 2010).
- **Platform as a Service (PaaS):** A cloud computing service that provides developers with the complete platform they need for the entire application lifecycle, including application development, testing and deployment. PaaS can speed up the application development process, reduce costs and provide ease of scaling. Features offered by PaaS providers include databases, application server software, web server software, push notification, workflow management, data analytics and many other services. For example, Google App Engine and Microsoft Azure PaaS services are popular (IBM, 2021).

Cloud computing services provide a huge advantage for businesses. These services enable businesses to easily access IT resources and customize them according to their needs. It also reduces costs for businesses and enables higher efficiency. Cloud computing services offer different types of services for businesses with different needs and, therefore, can be customized according to the needs of businesses (Mell & Grance, 2011).

Elastic Compute Cloud (EC2) is an IaaS cloud computing service provided by Amazon Web Services (AWS). EC2 allows businesses to move workloads to a cloud-based environment, enabling them to scale and manage them flexibly. EC2 allows users to create and manage virtual machines (VMs). Users can customize the virtual machines running under EC2's management to different sizes and capacities. Therefore, EC2 is a popular choice for hosting workloads, especially for web applications, databases, analytics and big data processing (Amazon, 2021).

## Cloud Computing Applications in the Public Sector

### *Use of Cloud Computing in the Public Sector*

Cloud computing has become increasingly widespread in the public sector in recent years. By using cloud computing services, the public sector is working to provide better services to citizens and to use public resources more effectively. Cloud computing services allow public organizations to provide more flexible, scalable, and accessible services (Görbil & Özkan, 2015).

The public sector can gain many benefits from cloud computing services. For example, cloud computing services enable public institutions to utilize IT resources more efficiently and reduce costs accordingly. Cloud computing services also offer significant advantages in terms of security, backup, and disaster recovery. The public sector can also benefit from cloud computing services in areas such as data analytics, geographic information systems, and public administration (Al Ali, et al., 2017; Kamble & Gunesekaran, 2019).

### *Cloud Computing Provider Selection in the Public Sector*

The choice of a cloud computing provider in the public sector is important from various perspectives, and a few of the reasons that show its importance for the sector are as follows:

*Identifying Needs*: Identifying the criteria enables the government organization to understand and identify its needs. Each organization may have different needs, so setting the right criteria helps the organization to choose the most suitable cloud computing provider to meet its requirements.

*Security and Data Protection*: In the public sector, security and data protection are of paramount importance. Setting criteria includes security requirements, compliance standards and data protection measures. In this way, the security and data protection policies of the provider can be evaluated and a provider that can offer a reliable service can be selected.

*Performance and Functionality*: Determining the criteria also includes the performance and functionality requirements of the organization. Factors such as the performance, speed, accessibility and scalability of the service that the cloud computing provider can offer are evaluated. A provider that can support the organization's business processes and increase efficiency may be preferred.

*Cost*: Setting criteria also includes cost factors. As there are budget constraints in the public sector, providers that offer favorable pricing models and flexible payment options may be preferred. At the same time, the cost-effectiveness and return on investment of the provider's service should also be assessed.

*Compliance with Local Regulations*: Organizations operating in the public sector often have to comply with local regulations. The cloud computing provider must comply with data storage location, data security standards, and other regulatory requirements. Therefore, setting criteria should include requirements for compliance with local regulations.

For these reasons, it is important to set the criteria correctly when selecting a cloud computing provider in the public sector. When choosing the right cloud computing provider, a public sector organization can use many sources. These sources include Gartner's Magic Quadrant reports for cloud computing providers, NIST's cloud computing reference architecture, ISACA's risk management framework for cloud computing, Cloud Security Alliance's cloud computing security standards, CIS Benchmarks' cloud computing recommendations, and BSI's cloud computing security criteria. These resources can help public sector organizations choose the right provider to provide secure, cost-effective, and scalable cloud computing solutions (Oracle, 2023).

## Methods Used

Multi-criteria decision-making methods are analytical tools and techniques that consider multiple criteria when making complex decisions. These methods structure the decision-making process, weight the criteria, evaluate the performance of alternatives, and rank the results. Utilized methods are:

- **AHP:** A method in which criteria and alternatives are evaluated in a hierarchical structure and pairwise comparisons are used. This method was developed by Thomas L. Saaty.
- **TOPSIS:** It is a ranking method that considers the similarity of alternatives to the ideal solution and their proximity to the ideal solution. This method was introduced by Hwang and Yoon.

Each of these methods uses different mathematical models and techniques and may be preferred according to specific situations and requirements. AHP uses both quantitative and qualitative criteria. TOPSIS" is another MCDM approach helps DMs to rank alternatives. Therefore, users need to consider their needs and goals when choosing a particular method (Belton & Stewart, 2002).

### *AHP*

AHP enables the evaluation of multiple criteria and alternatives in the decision-making process. The main objective of AHP is to determine the importance of different criteria and alternatives and select the most appropriate option based on these values. The AHP method is structured using a decision tree. In the decision tree, the main objective or goal is at the top level. Below are the main criteria and sub-criteria related to these criteria. Weighting is done according to the sub-criteria and the main criterion. Weights are determined using pair comparison matrices. In these matrices, each criterion or alternative is compared with the others. As a result of the comparison, priority values are obtained for each criterion or alternative. The AHP method uses a mathematical formula to calculate the resulting priority values. This formula standardizes the priority values and is used to obtain a total priority value. The total priority value indicates the importance of the criteria or alternatives and is used in the decision-making process (Saaty, 1982).

### *TOPSIS*

TOPSIS is used to evaluate and rank alternatives. This method takes into account the similarity of alternatives and their proximity to the ideal solution. The TOPSIS method provides an analytical approach to decision-making and provides an objective basis for ranking alternatives. Alternatives with higher closeness values tend to have better performance and are closer to the ideal solution. The basic steps of the TOPSIS method are as follows:

1. Creating a decision matrix: A decision matrix is created with the performance values of the alternatives to be evaluated according to the criteria.

2. Normalization: The values in the decision matrix are subjected to normalization. This process allows the values to be converted between 0 and 1 depending on the scale of each criterion.

3. Weighting: For each criterion, weighting factors are assigned that determine the degree of importance. These factors reflect the relative importance of the criteria.

4. Ideal solution identification: The positive ideal solution (PIS) and negative

ideal solution (NIS) vectors are calculated. The PIS is a vector containing the highest values for each criterion. NIS is a vector containing the lowest values for each criterion.

5. Calculating the closeness of the alternatives to the ideal solution: The Euclidean or Manhattan distance of each alternative to the PIS and NIS is calculated. These distances measure the closeness of the alternatives to the ideal solution.

6. Ranking of alternatives: Alternatives are ranked according to their proximity to the ideal solution. The higher the proximity value, the more preferable the alternative becomes.

One of the advantages of TOPSIS is that the criteria and weights can be set flexibly. The decision maker can influence the results by changing the importance ranking or weights of the criteria. In this way, the preferences and priorities of the decision-maker are taken into account. Another advantage of the method is that criteria of different scales can be compared thanks to the normalization of the data in the decision matrix. This avoids an incorrect ranking of criteria expressed in different units (Hwang, Yoon, 1981).

## Literature Review

Cloud computing technology and services are constantly evolving and changing. Literature research ensures that the latest developments in the industry are kept up to date. This increases awareness of new technologies, features, and service models and helps to establish criteria for the most up-to-date options. It also supports the decision process by building a solid knowledge base. Information from previous studies and expert opinions helps to make decisions based on objective data for the evaluation and selection of providers. A review of previous studies can reveal generally accepted evaluation factors, performance metrics, security and compliance requirements, and cost factors. The literature on the related topic was reviewed, but no similar studies were found in terms of subject matter. Therefore, the literature in question was reviewed with specific words. Related words: Cloud computing, multi-criteria decision-making methods in the public sector, effects of cloud computing, considerations in cloud computing, cloud computing application in the public sector, considerations in cloud computing preference, cloud computing vulnerabilities. In line with the related words, 5 articles were identified and the related studies are summarized below:

Öztürk (2022) emphasizes the importance of using scientific methods in the personnel recruitment of public institutions. In this context, it is emphasized that it is an appropriate policy for public institutions to make job-oriented personnel selection by using scientific methods in personnel recruitment. The study, which was carried out using the AHP-based PROMETHEE method, showed alternative personnel selection processes to decision-makers in public institutions. In the study, 13 candidates were evaluated in terms of 7 criteria: Corporate Culture, Communication Skills, Professional Experience, Problem-Solving Competence, Teamwork Competence, Organization Competence, and Career Development in line with literature research and expert interviews.

Çakır and Karabıyık presented a summary of a study for the selection of cloud storage service providers. The study aimed to select the best one among popular cloud storage companies such as Google Drive, Yandex.Disk, iCloud Drive, Dropbox, Box and One Drive. The criteria were determined as Monthly Fee, Ease of File Sharing, Elasticity, Security, Compatibility with Operating Systems, Ease of Use of Mobile Application, Customer Service, Synchronization Speed, Free Storage Space, Integration with Third Party Applications, Ease of Use on the Web and the weights of these criteria were evaluated using SWARA and COPRAS methods. The security criterion was determined as the most important criterion and Google Drive was evaluated as the best cloud storage service provider (Çakır & Karabıyık, 2017).

In Yaldır and Polat study; what should be considered in the selection process of e-DMS (electronic document management system) in public institutions is emphasized. It is aimed to reduce cost and time losses by managing the E-DMS (electronic document management system) selection process well. Multi-criteria decision making techniques such as AHP, Fuzzy AHP and TOPSIS were used to select the most appropriate software. With these methods, cost, reliability, integration and management, flexibility, support and service, usability and archiving criteria were weighted and the most appropriate software was selected. According to the findings, the reliability criterion was determined as the most effective criterion (Yaldır & Polat, 2016).

Keskin and collegues present a study in which the most appropriate service provider is determined according to cloud computing security requirements. In the study, criteria such as cyber-attack/vulnerability, management inadequacy, data protection, employee behavior and availability and sub-criteria under these criteria such as credential privacy, risk management compliance, security breach, service availability, communication failures between service providers, accessibility of cloud employees, qualification of cloud employees and illegal access were determined by using AHP, TOPSIS and AAS methods based on literature review and expert opinions. According to the results of AHP, TOPSIS and AAS, IB was found to be the most suitable service provider according to cloud computing security requirements. However, AHP and AAS results indicate that there is no significant difference between the alternatives (Keskin et al., 2020).

Uslu, and colleagues address the cloud service selection problem of a software company. The study addresses the optimal cloud service selection problem for a software company with 235 employees located in Ankara to process and store its data. Due to the increase in competition and data proliferation, the importance of using big data quickly is emphasized. Several criteria are considered to make the optimal choice among cloud service providers. Five main criteria were identified: memory utilization, CPU utilization, response time, service and cost. Under these main criteria, a total of 17 sub-criteria such as availability, reliability, data rate, security, customer satisfaction, performance, processing speed, storage/data center location, portability, interoperability, adaptability, convenience, transparency, network latency, capacity, service and functionality were identified (Uslu et al.,2019).

This literature review focuses on some case studies and methods related to the selection of cloud computing technology and services. The studies address decision-making processes for cloud computing service providers, personnel selection, e-CMS selection and cloud service selection using different criteria and different multi-criteria decision-making methods. Each study sheds light on the decision-making process related to the selection of cloud computing service providers by focusing on various criteria, methods, and results.

## Application

### Definition of the Problem

This study aims to help public sector organizations make the right choice by defining the criteria that they should consider when choosing a cloud computing provider. For this reason, the most appropriate criteria have been determined to understand the difficulties in the selection of cloud computing providers by public sector organizations and to realize the correct decision-making process. Criteria and alternatives were determined by conducting literature research and expert opinions according to the requirements of public institutions. With these shortcuts, solutions were made in AHP and TOPSIS methods.

### Criteria

Cloud computing services provide many advantages for businesses. However, it is important to choose a suitable cloud computing provider. When choosing, several factors should be considered. Businesses should evaluate factors such as security, pricing, performance, support services, data backup and recovery features, and organizational compatibility.

- **Security:** One of the most important issues in cloud computing services is security. Therefore, when choosing a cloud computing provider, it is important to evaluate how issues such as security policies, data security, authentication and data privacy are handled. It is also important to consider the provider's compliance with international data protection standards.
- **Pricing:** Cloud computing services are usually charged on a usage basis. Therefore, it is important to consider the provider's pricing policies and payment options. Also, benefits such as pre-determined price lock-ins and payment plans can be taken into account, especially in long-term contracts.
- **Performance:** Cloud computing services are important in terms of performance. Issues such as the capacity, speed and level of backup of the provider's servers and networks need to be evaluated. The availability of services and downtime should also be considered.
- **Support Services:** The support services provided by the cloud computing provider are also an important factor in making a choice. Issues such as technical support, problem resolution times, and customer support offered by the provider to its users should be evaluated.
- **Data Backup and Recovery:** Data backup and recovery is an important issue in cloud computing services. The provider's data backup and recovery policies and processes, and how to recover data in case of emergencies should be evaluated.
- **Organizational Compliance:** The suitability of the cloud computing provider to your organization's business needs should also be considered when making a choice. In particular, the provider must have sufficient experience and capability in regulatory compliance, data security and regulatory issues. (IBM, 2023).

## Application of the model

At the beginning of the apllication, Analytic Hierarchy Process (AHP) was used to identify the criteria to be considered in the decision-making process related to cloud computing provider selection (Öztürk & Biçer, 2021). These criteria were determined by reviewing the literature and studies based on expert opinions and evaluating the opinions of experts. AHP can also be used in combination with some other methods. In this study, it is used together with TOPSIS method for ranking alternatives. This approach are as follows:

***Step 1***: The problem is defined and the objective, criteria, and alternatives are given. The objective is placed at the top, criteria, and sub-criteria at the middle level, and alternatives at the bottom level. Figure 1 shows this structure.

***Step 2***: After the hierarchical structure is established, a comparative advantage matrix is created in which each criterion or alternative is compared with all other criteria or alternatives. Each cell represents a comparison of two different criteria or alternatives and is evaluated on a scale and the comparative advantage matrix is shown in Table 1.

**Table 1.** *Comparative Advantage Matrix*

| Criteria | G | F | P | DH | VYVK | KU |
|---|---|---|---|---|---|---|
| Security | 1,00 | 1,42 | 0,54 | 1,94 | 1,26 | 2,66 |
| Pricing | 0,70 | 1,00 | 0,32 | 0,79 | 0,74 | 1,09 |
| Performance | 1,85 | 3,16 | 1,00 | 2,54 | 2,54 | 2,33 |
| SS | 0,51 | 1,26 | 0,39 | 1,00 | 0,74 | 1,27 |
| DB&R | 0,79 | 1,35 | 0,39 | 1,35 | 1,00 | 1,47 |
| CC | 0,38 | 0,92 | 0,43 | 0,79 | 0,68 | 1,00 |
| Total | 5,24 | 9,11 | 3,07 | 8,41 | 6,95 | 9,83 |

***Step 3***: In this step, the values obtained from the comparative advantage matrix are normalized and transformed into a range between 0 and 1. The normalization process scales the values of each criterion in such a way that their sum is equal to 1. This allows the criteria to be converted into a format suitable for comparing their relative weights. The normalized matrix helps to determine the ranking of the importance of the criteria and which criteria should be given more weight in the decision-making process is shown in Table 2.

***Step 4:*** In this step, the values in the normalized matrix are multiplied so that the weights of the criteria reflect the availability measure. The "Total" column in the table represents the weight of each criterion. The values in this column indicate how important each criterion is relative to the total impact. A higher weight value indicates that the criterion has more importance and Table 3 shows the measurement of the availability of the weights.

**Table 2.** *Normalized Matrix*

| Criteria | | F | P | DH | VYVK | KU | Kriter Ağırlığı |
|---|---|---|---|---|---|---|---|
| Security | 0,19 | 0,16 | 0,18 | 0,23 | 0,18 | 0,27 | 0,20 |
| Pricing | 0,13 | 0,11 | 0,10 | 0,09 | 0,11 | 0,11 | 0,11 |
| Performance | 0,35 | 0,35 | 0,33 | 0,30 | 0,36 | 0,24 | 0,32 |
| SS | 0,10 | 0,14 | 0,13 | 0,12 | 0,11 | 0,13 | 0,12 |
| DB&R | 0,15 | 0,15 | 0,13 | 0,16 | 0,14 | 0,15 | 0,15 |
| CC | 0,07 | 0,10 | 0,14 | 0,09 | 0,10 | 0,10 | 0,10 |

**Table 3.** *Measurement of the Availability of Weights*

| Criteria | G | F | P | DH | | KU | Toplam |
|---|---|---|---|---|---|---|---|
| Security | 0,20 | 0,16 | 0,17 | 0,23 | 0,19 | 0,27 | 1,22 |
| Pricing | 0,14 | 0,11 | 0,10 | 0,10 | 0,11 | 0,11 | 0,67 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Performance | 0,37 | 0,35 | 0,32 | 0,30 | 0,37 | 0,24 | 1,95 |
| SS | 0,10 | 0,14 | 0,13 | 0,12 | 0,11 | 0,13 | 0,73 |
| DB&R | 0,16 | 0,15 | 0,13 | 0,16 | 0,15 | 0,15 | 0,89 |
| CC | 0,08 | 0,10 | 0,14 | 0,09 | 0,10 | 0,10 | 0,61 |
| | | | | | | | |

***Step 5***: Consistency analysis is used to assess how consistent the method used in the decision-making process is. The CI value measures the consistency of the preference matrix and is checked against the RI value. If the CI value is smaller than the RI value, the preference matrix is acceptably consistent. The consistency analysis is shown in Table 4.

**Table 4.** *Consistency Analysis*

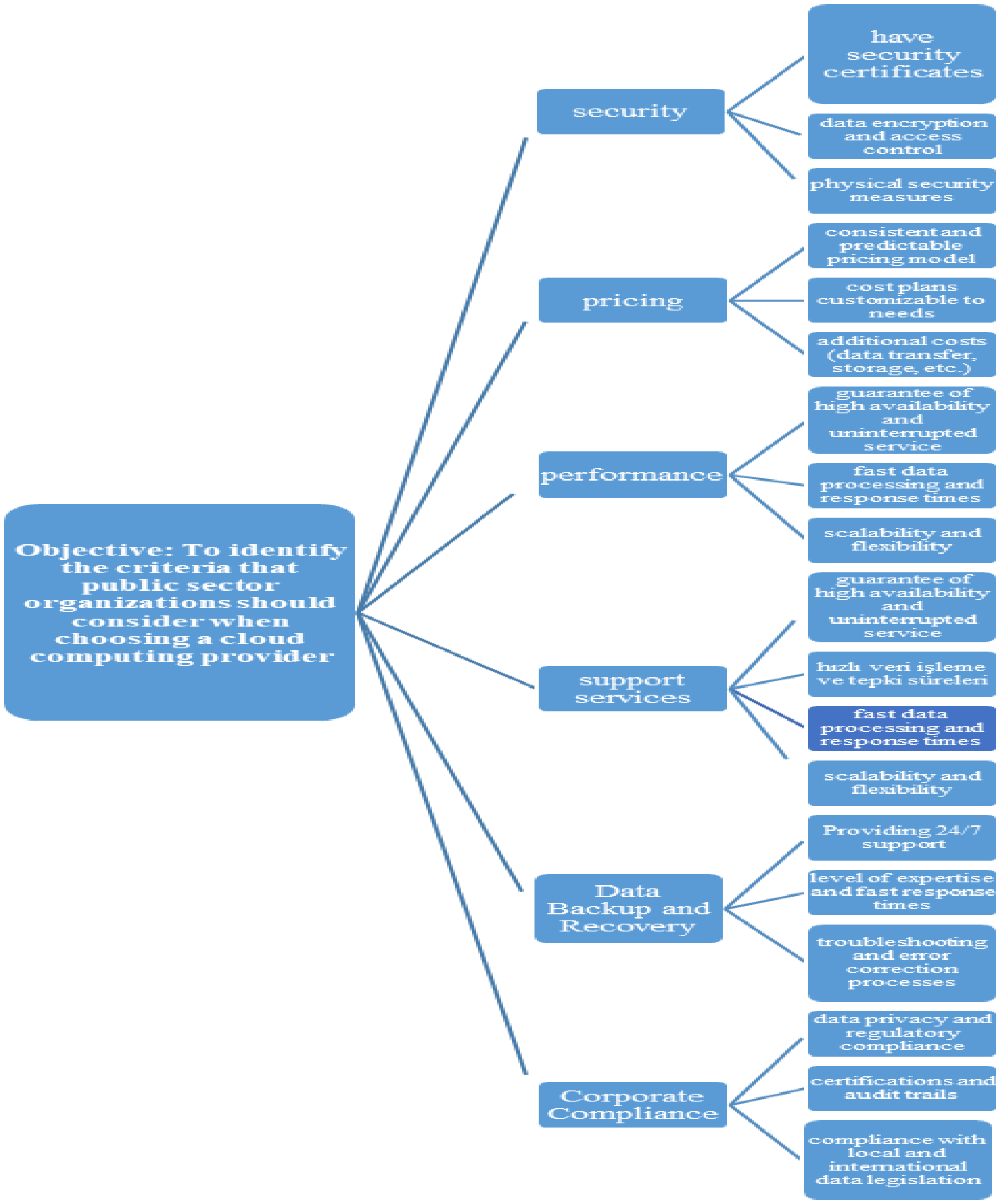
| Criteria | Total | Criteria Weight | T/C | Average | Landa | CI | RI | |
|---|---|---|---|---|---|---|---|---|
| Security | 1,22 | 0,20 | 6,20 | 6,05 | 6,05 | 0,01 | 0,0076 | <0,1 |
| Pricing | 0,67 | 0,11 | 6,00 | | | | | |
| Performance | 1,95 | 0,32 | 6,06 | | | | | |
| SS | 0,73 | 0,12 | 5,99 | | | | | |
| DB&R | 0,89 | 0,15 | 6,05 | | | | | |
| CC | 0,61 | 0,10 | 5,99 | | | | | |

The outputs obtained from the AHP study provide an introduction to the TOPSIS study. The pairwise comparison matrix for the criteria is shown in Table 5. After scoring the cloud service providers in terms of criteria, the criteria were normalized as the second step. The Normalized Matrix stage is an important step in MCDM methods.

**Table 5.** *Geometric Mean Matrix by Criteria*

| | | Geomertic Average | | | | | |
|---|---|---|---|---|---|---|---|
| Stage 1 | Criteria | Security | Pricing | Performance | SS | DB&R | CC |
| | Amazon Web Services (AWS) | 5,82 | 5,78 | 4,05 | 4,96 | 8,02 | 4,96 |
| | Microsoft Azure | 4,89 | 5,37 | 5,08 | 4,25 | 6,44 | 5,29 |
| | Google Cloud | 4,89 | 5,14 | 4,07 | 5,14 | 6,96 | 4,42 |
| | Pcloud | 4,92 | 6,36 | 5,08 | 4,89 | 5,95 | 4,68 |
| | Sync.com | 6,58 | 5,49 | 4,25 | 3,84 | 5,71 | 4,45 |
| | Dropbox | 4,07 | 4,01 | 3,60 | 3,84 | 3,76 | 3,42 |
| **Criteria Weights** | | 0,20087 | 0,1097 | 0,32149 | 0,11986 | 0,14717 | 0,10083 |

**Figure 1.** *Hierarchical Structure*




Each cell in the normalized matrix shows the impact of the criterion on the relevant provider. The normalization results in the table provide a more accurate assessment of the relative importance of the criteria and the performance of the service providers, and the resulting normalized matrix is shown in Table 6.

**Table 6.** *Normalized Comparisons of Criteria*

| Stage 2 | **Normalize Matris** | | | | | | |
|---|---|---|---|---|---|---|---|
| | Criteria | Security | Pricing | Performance | SS | DB&R | CC |
| | Amazon Web Services (AWS) | 0,45182 | 0,4361 | 0,37693 | 0,44787 | 0,52141 | 0,44277 |
| | Microsoft Azure | 0,38001 | 0,4051 | 0,472698 | 0,38395 | 0,41910 | 0,47192 |
| | Google Cloud | 0,38001 | 0,3884 | 0,378209 | 0,46457 | 0,45267 | 0,39434 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pcloud | 0,38220 | 0,4801 | 0,472698 | 0,44201 | 0,38717 | 0,41814 |
| | Sync.com | 0,51105 | 0,4149 | 0,395239 | 0,34697 | 0,37134 | 0,39692 |
| | Dropbox | 0,31587 | 0,3031 | 0,334339 | 0,34697 | 0,24445 | 0,3055 |

After the calculation of the normalized matrix, the third stage was started and weighted performance values were calculated by multiplying the weight values to the normalized matrix values of the criteria. By multiplying the weight values to the Normalized Matrix values, the weighted performance values of each provider according to the criteria are calculated and the final matrix is shown in Table 7. After the calculation of the normalized matrix and the weights, in the Best-Worst Value stage, the highest and lowest performance values for each criterion were determined. The service providers with the best performance values show that they perform better than others in a particular criterion, while the service providers with the worst performance values show a weaker performance than others in that criterion. Table 8 shows the best and worst performance values with P+ and P- values.

**Table 7.** *Weighting of the Normalized Decision Matrix*

| Stage 3 | **Weight Values * Normalized Matrix** | | | | | | |
|---|---|---|---|---|---|---|---|
| | Criteria | Security | Pricing | Performance | SS | DB&R | CC |
| | Amazon Web Services (AWS) | 0,09075 | 0,04787 | 0,121183 | 0,05368 | 0,07674 | 0,044648 |
| | Microsoft Azure | 0,07633 | 0,04447 | 0,151972 | 0,04602 | 0,06168 | 0,047587 |
| | Google Cloud | 0,07633 | 0,04263 | 0,121594 | 0,05568 | 0,06662 | 0,039764 |
| | Pcloud | 0,07677 | 0,05270 | 0,151972 | 0,05298 | 0,05698 | 0,042165 |
| | Sync.com | 0,10265 | 0,04554 | 0,127069 | 0,04158 | 0,05465 | 0,040024 |
| | Dropbox | 0,06345 | 0,03327 | 0,10749 | 0,04158 | 0,03597 | 0,030806 |

**Table 8.** *Positive and Negative Ideal Solutions*

| Stage 4 | **Best - Worst Value** | | | | | | |
|---|---|---|---|---|---|---|---|
| | Criteria | Security | Pricing | Performance | SS | DB&R | CC |
| P+ | | 0,090757 | 0,047871 | 0,121183 | 0,053683 | 0,076741 | 0,04464 |
| P- | | 0,076333 | 0,044471 | 0,151972 | 0,046021 | 0,061684 | 0,04758 |

The fourth and fifth stages were used to determine the Si+ and Si- values. The distance of the weighted values to the positive ideal solutions (S+) and the distance to the negative ideal solutions (S-) were calculated. These values are reflected in Table 9.

**Table 9.** *Separation Measures*

| Stage 4 & 5 | | |
|---|---|---|
| | Si+ | Sİ- |
| Amazon Web Services (AWS) | 0,033549 | 0,056086 |
| Microsoft Azure | 0,032874 | 0,056851 |
| Google Cloud | 0,043366 | 0,040873 |
| Pcloud | 0,033121 | 0,056865 |
| Sync.com | 0,037617 | 0,050048 |
| Dropbox | 0,077686 | 0 |

In the sixth stage, cloud service providers are analyzed in terms of their scores and rankings, and Table 10 reflects the score and rank values of each provider. Higher score means better performance and these scores were used to rank the cloud computing providers.

**Table 10.** *Ranking of Alternatives*

| Stage 6 | | | |
|---|---|---|---|
| | Cloud Service Providers | Score | Rank |
| | Amazon Web Services (AWS) | 0,625715 | 3 |
| | Microsoft Azure | 0,633612 | 1 |
| | Google Cloud | 0,485202 | 5 |
| | Pcloud | 0,63193 | 2 |
| | Sync.com | 0,570897 | 4 |
| | Dropbox | 0 | 6 |

## Comparison of Results and Discussions

According to Table 1, the criterion with the highest total value is "Organizational Compliance" (9.83). Second most important criterion: The criterion with the second highest total value is "Support Services" (8,41). The "Price" criterion has the third highest total value (9.11). Data backup and recovery: "Data Backup" criterion (6.95) ranks fourth, the "Performance" criterion (3.07) ranks fifth, and the "Security" criterion (5.24) ranks sixth. In Table 2, the "Performance" criterion has the highest normalized weight (0.32). This indicates that performance is of great importance for the cloud computing provider to be selected. The criteria "Security" (0.19) and "Data Backup" (0.15) also have significant weights. These indicate that the security and data backup processes of the provider should be taken into consideration. The other criteria, "Price" (0.11), "Support Services" (0.12), and "Organizational Compliance" (0.10), have lower weight values. This indicates that the overall impact of the criteria is less significant, but still some factors should be considered in the evaluation. Table 3 shows that the "Performance" criterion has the highest weight, while the "Security" criterion has the second highest weight, and the "Price" and "Corporate Compliance" criteria have low weights. Consistency analysis was performed in Table 4, and the Consistency Index (CI) value was calculated as 0.01 and the Random Index (RI) value was calculated as 0.0076, which is consistent at an acceptable level.

According to the results of TOPSIS solutions in line with the solutions made in the application, first of all, Amazon Web Services (AWS) has the highest Geometric Mean value in Table 5. It shows that it exhibits the best performance considering all criteria. Dropbox, on the other hand, has the lowest Geometric Mean value. When we look at the results in Table 6, we can see more clearly how each service provider performs according to the criteria. Since Sync.com has the highest value in the “Security” criterion, it is evaluated as a more secure option than other service providers. Similarly, in the “Price” criterion, Dropbox was rated as a more cost-effective option than other providers as it had the lowest value. According to the results in Table 7, by looking at the weighted performance values, the alignment of each service provider with the criteria can be seen more clearly. Amazon Web Services (AWS) has the highest weighted performance value in the “Security” criterion. Considering the weight values and normalized matrix values, it is found that it performs the best in terms of security. According to the results in Table 8, the distance to positive and negative ideal solutions is determined by P+ and P- values. In the “Safety” criterion, the best performance value is 0.90757 for P+ and the worst performance value is 0.076333 for P-. According to the results in Table 9, the cloud service provider with the highest Si+ value is Dropbox, while the provider with the highest Si- value is Microsoft Azure. According to the results in Table 10, Microsoft Azure has the highest score (0.633612) and ranks 1st, indicating that its overall performance is the best compared to other providers. Pcloud has the second highest score (0.63193) and is ranked in 2nd place. It scored very close to Microsoft Azure and its overall performance was also rated as very good. Amazon Web Services (AWS) ranked third, Sync.com ranked fourth and Google Cloud ranked fifth. Although these providers achieved good results in terms of overall performance, they were slightly behind Microsoft Azure and Pcloud. Dropbox ranked sixth with the lowest score, indicating that its overall performance was weaker than the other providers. From this analysis, it can be said that Microsoft Azure and Pcloud are the best performing providers. However, each provider has different strengths and weaknesses and it is important to consider other factors when choosing.

## Conclusion

This research was conducted to determine the criteria that public sector organizations should consider when choosing a cloud computing provider and to guide the right decision-making process. The 7 experts in the study are IT personnel working in the public sector and using cloud computing services. With the increasing demand for cloud computing services, public organizations face difficulties in choosing the right provider. This paper presents an analytical framework to help organizations overcome these challenges and select the most suitable provider for their needs. Based on literature research and expert opinions, 5 criteria and 6 alternatives were identified for analysis and applied using AHP and TOPSIS methods. In the stepwise analysis process, various sub-criteria and alternative service providers were evaluated under the main criteria such as security, pricing, performance, support services, data backup and recovery, organizational compliance. Based on the results of the analysis, it is seen that the performance service criterion is an important factor in the selection of cloud computing providers by public sector organizations. Public sector organizations will want to choose a provider that offers a fast and reliable service. The performance criterion is also a criterion with the highest priority. Security is the second most important criterion, as organizations, especially those with sensitive and confidential data, want to ensure that their data is secure. Therefore, security was identified as the second highest priority criterion. The organizational alignment criterion was ranked lower compared to the other criteria. This is because security, performance, support services and data backup/recovery are considered higher priorities. Nevertheless, data compliance and regulatory compliance is an important issue for public sector organizations and should be considered in the selection process. According to the analysis of the alternatives, Microsoft Azure ranked highest in terms of its overall performance. It achieved high scores in security, price, performance, support services, data backup and organizational alignment criteria. This suggests that Microsoft Azure is a good option for businesses to choose when migrating to cloud-based services. Pcloud ranked second, just behind Microsoft Azure. It achieved good results in security, price, performance, support services and organizational alignment. Pcloud can be considered a reliable option for organizations to meet their file storage and sharing needs. Amazon Web Services (AWS) performed strongly in the performance, support services and data backup criteria. With its wide range of services and scalability, AWS can be an advantageous option for businesses to adapt to their growth and needs. Dropbox underperformed compared to other providers. It scored poorer on security, performance and data backup. Dropbox may be preferable for individual users and small businesses. As a result, this study provides a framework that can help public sector organizations make an objective assessment of cloud computing provider selection. The results obtained will enable organizations to make the right decisions when selecting the most suitable provider for their needs. However, it should be kept in mind that each organization has different requirements and the decision-making process should be managed accordingly. The limitations of the study should also be considered. The study is based on a limited amount of existing literature research and expert opinions. The cloud computing industry is a constantly evolving field and new providers may emerge or existing providers' services may change. Therefore, it is important to conduct regular reviews based on up-to-date data. In addition, this study only evaluates providers based on established criteria. Each public institution has its own specific needs, policies and objectives. Therefore, organizations need to define their own criteria taking into account their priorities and evaluate providers based on these criteria. In future studies, it may be useful to analyze the cloud computing provider selection processes of different public institutions and identify institution-specific criteria. The results of this study can guide public sector organizations to make criteria-based decisions when choosing the right service provider. In this way, public sector organizations can provide more secure, efficient and compliant cloud computing services.

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CHAPTER

# The Use and Integration of Robot Technology in Education

9

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## Introduction

Robot is a device consisting of electronic and mechanical systems capable of performing pre-programmed or autonomous given tasks. According to the current definition, robots are devices composed of electronic and mechanical units, possessing sensing capabilities and programmable features. In another definition, robots are interdisciplinary engineering products capable of mimicking the functions and behaviors of living beings, possessing physical abilities and artificial intelligence (Şişman, 2016).

Robots are versatile machines capable of operating both under the direct control of an operator and carrying out tasks guided by a computer program. Although robots are commonly thought of as human-like machines, the reality is that only a very small fraction of robots resemble humans.

Robots are classified based on their areas of use and the tasks they perform. One of the most common applications of robots today is in industrial production. Particularly in the automotive industry, a wide range of robots is used. Most of these robots are designed in arm-like shapes and are capable of assembling, joining, welding, and performing painting processes.

The rapid advancements in technology in the 21st century have made the use of technology in education essential. The utilization of robots has begun to expand not only in engineering but also in the field of education (Beran at al., 2011). The idea of using robots in education emerged in the early 1980s (Şişman, 2016). With developments in technology, robots have started to be used more actively in education.
Robots are considered valuable tools for enhancing students' skills from early childhood education to the end of university education in today's context (Alimisis, 2013). Additionally, they support learning in science, mathematics, technology, information technology, and other school subjects or interdisciplinary learning activities (Alimisis & Kynigos, 2009). Developed for educational purposes, robots are utilized as a unique learning tool that provides practical engagement in an interactive learning environment, offering enjoyable activities and increasing students' interest and curiosity (Curto & Moreno, 2016).

## Robot Technologies in Education

Robotics in Education," known as robot-based projects, has become a critical tool for future engineers and scientists to acquire skills. These projects, integrating robots into classroom settings in schools and universities, offer students a more engaging and enjoyable perspective on science and engineering topics. Consequently, students gain opportunities to observe the direct practical applications of theoretical concepts in mathematics and technology. These robotics projects not only enable students to learn beyond textbooks but also help them develop skills to generate and implement solutions for real-world problems. This opportunity not only aids their education but also lays a robust foundation for their future careers (Curto & Moreno, 2016).
The successes in the field of robotics have significant potential in addressing various challenges encountered in education (Benitti,2012). Education requires teaching in ways that accommodate students' different learning styles and paces. The science of robotics can offer customizable learning tools and methods to support instructional processes in this regard. Furthermore, the use of robotic technologies can be planned to tackle issues such as teacher shortages or inequalities in education. For instance, concepts involving the development of robotic assistants for remote education or to support teachers could offer solutions to these challenges. Consequently, advancements in the field of robotics can contribute significantly to providing a more effective, accessible, and personalized learning experience in education.

Particularly, robotics offers a unique learning experience by providing tailored and beneficial solutions to each student's learning needs. In this context, Educational Robotics encompasses various distinct subfields of robotics. Considering the applications of robotic devices, it is possible to define four main areas in education: Assistive robotics, social robotics, socially assistive robotics, and educational robotics (Scaradozzi, Screpanti & Cesaretti, 2019). These subfields support and enrich learning processes by encompassing various aspects of robot technology in education. In this way, it allows students to have a more effective, personalized, and engaging learning experience (Ciuccarelli et al., 2018; Foresi et al., 2018).

Based on the Maker principle and typically consisting of several unassembled components, reprogrammable robot kits assist students in developing various competencies in technology and related fields within Educational Robotics (Prist et al., 2014). These educational robot kits not only provide students with technical skills but also offer opportunities to enhance soft skills such as communication and teamwork. Thus, activities involving educational robots enable students to strengthen a broad spectrum of abilities, not only improving their technical prowess but also fostering social skills like collaboration and leadership.

## Areas of Use and Integration of Robot Technologies in Education

Robot technologies are utilized in various fields across all levels of education. Robots are employed in education in three different ways: as instructional material, as peer instructors, and as assistant teachers (Şişman, 2016).

Today, there exists a wide range of educational robots and robot kits, ranging from low-cost, minimally functional kits to humanoid robots costing thousands of dollars, used as instructional materials. Some of the most commonly used popular educational robot kits include VEX IQ Education, Robotis STEM, Lego Mindstorms Education, Sphero, Bee-Bot, mBot, and open-source development boards like Arduino. Educational robot kits not only teach mechanical assembly and programming skills but also provide education and skills related to electronics. For instance, kits like Arduino are entirely programmable, allowing students to construct robots, create electronic circuits, and upload command files (Balogh, 2010). Figure 1, Figure 2, and Figure 3 respectively illustrate Robotis STEM Education kit, Lego Mindstorms Education kit, and Arduino education kits.

**Figure 1.** *Robotis STEM Education Kit*


**Figure 2.** *Lego Mindstorms Education Kit*

**Figure 3.** *Arduino Education Kit*


Some robot kits have the capacity to teach a wide range of subjects such as computer science and programming (Powers et al., 2006), engineering, language (Mubin et al., 2012), physics, and robotics. In education, among more advanced systems, there are fully humanoid robots (Tanaka & Matsuzoe, 2012) or robots resembling pets or toy characters. Such robots possess the capability to engage in social interaction due to their speech abilities and the ability to display facial expressions. They are used specifically to engage in certain forms of social interaction and are often preferred for teaching non-technical subjects like language or music.

Humanoid robots, standing out with their ability to engage in social interaction by possessing physical characteristics and abilities similar to humans, are a significant component of the field of Interactive Robotics. These artificial entities, also known as social robots, are specially designed to communicate with humans and behave as part of the human society (Kanda & Ishiguro, 2004).
Social robots used in education function as teachers or companions for students, making learning environments interactive and interconnected. These robots are designed to capture students' interest and present lessons in a more interactive manner. Additionally, socially assistive robots can help reduce social disorders among students. By communicating through social interaction rather than physical interaction with users, these robots can contribute to students' emotional and social development (Pivetti et al., 2020). In this way, social robots play a significant role in providing a more effective learning experience in education and enhancing students' social skills. Particularly in areas such as special education and foreign language education, these robots possess unique potential to support students and enhance their learning processes (Şişman, 2016).

**Table 1.** *Some Studies on the Use of Robots in Education.*

| | | | | | |
|---|---|---|---|---|---|
| **Teacher** | An android robot named SAYA at an elementary school in Tokyo and an anthropomorphic RoboThespian at MadaTech Science Museum were used in a Science lesson (Hashimoto et al., 2013). | KASPAR, an anthropomorphic robot, has been used in the education of children with autism (Costa et al., 2013). | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Teaching assistant** | Humanoid robots have been used to teach sign language to deaf children through interactive games (Kose, Akalin & Uluer, 2014). | A humanoid NAO model robot was utilized as an assistant psychologist in two private hospitals in Tehran (Alemi et al., 2014). | Humanoid robots have been used in teaching second language acquisition to elementary school students (Chang et al., 2010). | Robots have been used in music education (Han et al., 2009). | In humanoid robot usage within elementary level Technology and Science classes has been observed (Chin et al., 2011). |
| Peer Tutor | Robots have been used to teach English verbs to children aged 3 to 6 (Tanaka & Matsuzoe, 2012). | Two humanoid robots were used for social communication purposes at the secondary education level (Kanda & Ishiguro, 2004). | A humanoid robot was used to teach arithmetic to 20 children aged 9-10 (Janssen et al., 2011). | | |
| Teaching Material | model robot named IROBI was used for the purpose of teaching English (Han & Kim, 2005). | Robot kits have been used for teaching programming languages (Lin & Kuo, 2010). | Robots have been used for artificial intelligence projects (Kumar, 2004). | In an undergraduate course on Artificial Intelligence, LEGO robot kits were utilized (Imberman, 2003). | |

In the field of special education, particularly in the education and therapy of children with Autism Spectrum Disorder (ASD), humanoid robots are being used to facilitate social interaction. Children with Autism Spectrum Disorder often exhibit indifference to their surroundings, struggle to initiate social interaction independently, experience difficulty in sustaining communication, and tend to avoid making eye contact (Ekiz, Şahin & Camadan, 2014). According to the results of scientific studies and data obtained, research conducted on individuals with Autism Spectrum Disorder has indicated that robot technology captures the attention of these individuals and encourages interaction with robots, facilitating the establishment of eye contact (Dautenhahn, 1999; Michaud, Théberge-Turmel, 2002; Costa et al., 2015).

Education robots play a significant role not only in special education but also in foreign language instruction. In teaching foreign languages, these robots can serve as important aids in enhancing students' speaking, listening, and vocabulary-building skills. These technological tools, supporting the natural process of language acquisition, assist students in learning the language more rapidly and effectively (Cincioğlu, Şişman & Yaman, 2015). Numerous studies have focused on English language instruction, utilizing robots with various features. In one such study, an IROBI model robot was utilized (Han et al., 2005). The IROBI robot is equipped with an LCD screen and programmed to support English speech entirely. Three separate groups, each comprising ten children of both genders, received lessons with identical content. Research outcomes indicated that education materials supported by robots yielded the most positive results concerning children's learning performance, interest in learning, and academic achievements. Researchers concluded that robot-assisted learning proved to be more effective in children's English language learning success compared to other methods (Şişman, 2016).

**Figure 4.** *IROBI Robot (Han et al.,2008)*

Another study conducted in Japan focused on the use of robots in education, specifically examining English language learning at the elementary school level through the ROBOVIE robot.

ROBOVIE contains behavioral examples with certain English dialogues based on 800 rules stored in its memory. In order to determine the effects of a robot on English language learning, researchers placed a robot in a primary school for two weeks, spanning from first to sixth grades, and compared students' English test scores with their interaction frequency with the robot. It was noted that there was a significant increase in the English grades of students who showed interest. This suggests that robot-assisted English learning might be effective in motivating students (Kanda et al., 2004) (Han et al., 2008). In their study, researchers examined the use of a humanoid robot in teaching foreign languages to elementary school students. They investigated the robot's utilization in storytelling, reading, fostering friendships, receiving commands, and engaging in question-answer activities. The study demonstrated that the robot had a positive impact by increasing students' interest and making learning more enduring. An image from the study is provided in Figure 5 (Chang et al., 2010).

**Figure 5.** *The teacher is narrating a story with a humanoid robot ( Chang et al.,2010)*

Robots have been utilized in music education (Han et al., 2008), in teaching programming languages at the primary and secondary education levels (Lin et al., 2010), in undergraduate and graduate-level artificial intelligence courses (Kumar, 2004), as an assistant teacher in Technology and Science classes at the elementary school level (Chin et al., 2011), in Science and STEM classes (Hashimoto et al., 2013), and for teaching arithmetic to 20 children aged 9-10 (Janssen et al., 2011).

## Conclusions and Recommendations

The landscape created by robotics education includes a range of applications that will be beneficial in the lives of students and teachers. Various technological tools and systems catering to different functions and age groups are available, which help meet diverse needs.

Many schools, even in their regular activities, incorporate robotics to enhance knowledge and competitiveness in scientific and technological fields. Particularly, according to research conducted by (Cantarini & Polenta, 2021), across Europe, promoting technology, robotics, and a culture of science has increased achievement and motivation starting from the elementary school level.

However, despite the widespread presence of robot technology and tools, there remains a certain uncertainty in classrooms regarding coping with technology and evaluating the outcomes of such activities. In reality, although technological advancements have triggered a digital revolution in education, the lack of guidelines on integrating robotics into education and the challenges in assessing the complex skills generated by these new practices hinder teachers and schools from fully leveraging robotics technologies and exploring the benefits technology can bring (Alimisis, 2013).

It is clearly evident that a review of the existing approaches in Educational Robotics is necessary. Robotics holds significant potential in education, but the benefits guaranteed solely by the use of robotics in classrooms for students' learning are not assured. There are many factors influencing learning, and technology alone does not possess the capability to teach (Alimisis, 2013).

The results and findings of the studies conducted on the use of robots in education are presented here. According to this data, it has been generally concluded that robots increase students' interest and motivation. Motivation, as it enhances an individual's energy and prompts them to act willingly, is one of the most crucial factors emphasizing effectiveness in the teaching-learning process (Akbaba, 2006).

To enhance students' active participation in classes and to foster greater interest in lessons, creating interactive environments is crucial. Robots can assist in drawing students' attention and engaging them actively in lessons.

Educational Robotics should be acknowledged as a tool for enhancing essential life skills (intellectual and personal development, teamwork). This way, individuals can develop their potential to utilize imagination, express the ability to make original and valuable choices. The benefits of educational robotics and robotics, in general, are crucial for all children.

Therefore, there is a need for comprehensive projects that support creativity skills, aiming to enhance children's creativity abilities irrespective of their school inclinations or genders (Alimisis, 2013).

When examining research and applications, it has been observed that students can learn information from robots in various fields. Educational robots and robot kits are expected to be used in many fields of education in the near future due to the decrease in costs of robotics, advancements in robots' ability to interact with humans, and ongoing efforts to enhance human-robot interactions (Cincioğlu, Şişman & Yaman, 2015).

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CHAPTER

# Robotic Systems and Artificial Intelligence Applications in Agriculture

10

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## Introduction

Two significant transformations have occurred in human history. The first is a process known as the agricultural revolution, while the other is the industrial revolution, which significantly reduced the population engaged in agriculture worldwide, transforming people into individuals increasingly involved in production and manufactured goods. The latest stage of this transformative process is marked by advancements in science and technology, particularly in the fields of robotics and artificial intelligence (Güran, 1990).

Artificial intelligence refers to an engineering discipline that transfers human intelligence characteristics into computer systems and develops algorithms. Robotics, on the other hand, is a field encompassing various disciplines, aiming at the production, design, and utilization of intelligent machines to perform tasks typically carried out by humans.

Artificial intelligence systems are structures that analyze the cognitive functions of human intelligence through computer models, integrating these abilities into different systems equipped with human-like capabilities such as information gathering, perception, learning, thinking, and decision-making (Bozüyük et al., 2005).

The artificial intelligence methods used in artificial intelligence applications are categorized as follows: (Alpaydın, 2004):

- Classification is the process of determining which class new data belongs to by specifying the classes of past data.
- Clustering, on the other hand, involves grouping data based on their similarities when past data hasn't been classified or is unknown.
- Regression or curve fitting involves creating a curve model from past data when the data consists of continuous numerical values.
- Feature selection involves identifying the features that affect classification in large datasets. This process may involve creating subsets from existing features or deriving new features from their combinations.
- Association inference involves analyzing relationships between data to identify the most frequently occurring data together.
- Agriculture is defined as the entirety of activities conducted on land to obtain necessary plants to fulfill humanity's vital needs.

Artificial intelligence is a fundamental research field in computer science, rapidly spreading due to its strong applicability in solving problems that are difficult for humans and in traditional computing structures. One of these areas is agricultural activity conducted on 2,781 million hectares of agricultural land, where 30.7% of the world's population works. The agricultural process involves various challenges, including pest and disease control, chemical management, weed control, yield predictions, and irrigation errors. (Bannerjee et al., 2018).

Various technological devices are utilized in the agriculture industry. Equipment such as tractors, combines, harvesters, fertilizing machinery, irrigation systems, agricultural aircraft, farming robots, and agricultural sensors are included in these tools1. Within the agricultural sector, an approach known as precision farming enables the optimization of agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of artificial intelligence in areas like weather forecasting, irrigation management, and soil analysis is becoming more prevalent. Artificial intelligence facilitates the early detection of plant diseases and pests in the agricultural sector, thereby optimizing intervention processes for farmers (Kocaoglu, Gumuslu, Guven,  Baz, Erol-Barkana, & Soğutmaz-Ozdemir. 2021).

The agriculture industry can be managed more efficiently, sustainably, and intelligently with the assistance of artificial intelligence technology. Artificial intelligence is employed across various domains within the agricultural sector. For instance, an approach known as "precision farming" optimizes agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasingly prevalent. This technology aids in the early detection of plant diseases and pests, optimizing intervention processes for farmers. AI technology facilitates in-depth research on plant genetics and productivity. Moreover, the increasing use of AI in processes such as the storage and distribution of agricultural products could help reduce food waste and enhance food security. Furthermore, robotic technologies are also utilized in the agricultural sector. Robots, for instance, can replace agricultural workers in conducting harvesting operations, while robotic arms integrated into farming machinery perform tasks like plant harvesting, pruning, and spraying. These robotic technologies enhance workforce efficiency in agriculture, reducing the workload for farmers (Sahin, 2022).

The agriculture industry can be managed more efficiently, sustainably, and intelligently with the assistance of artificial intelligence technology. Artificial intelligence is employed across various domains within the agricultural sector. For instance, an approach known as "precision farming" optimizes agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasingly prevalent. This technology aids in the early detection of plant diseases and pests, optimizing intervention processes for farmers. AI technology facilitates in-depth research on plant genetics and productivity. Moreover, the increasing use of AI in processes such as the storage and distribution of agricultural products could help reduce food waste and enhance food security. Furthermore, robotic technologies are also utilized in the agricultural sector. Robots, for instance, can replace agricultural workers in conducting harvesting operations, while robotic arms integrated into farming machinery perform tasks like plant harvesting, pruning, and spraying. These robotic technologies enhance workforce efficiency in agriculture, reducing the workload for farmers (Tarlasera, 2023; tarlaio, 2023;Celikten,2020).

Artificial intelligence can be utilized across various fields within the agricultural sector. One of these domains, known as "precision farming," improves agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Moreover, the use of AI in areas such as weather forecasting, irrigation management, and soil analysis is increasing. AI contributes to the early detection of plant diseases and pests in agriculture, enhancing intervention processes for farmers. AI technology enables more extensive studies on plant genetics and productivity. Additionally, the use of artificial intelligence in processes like the storage and distribution of agricultural products may increase, aiding in reducing food waste and enhancing food security (*TÜBİTAK Bilim Genç, 2023;* Tarlaio, 2023).

As a part of smart agriculture, various technologies are involved, including sensors, remote sensing drones, satellite technologies, artificial intelligence, robot technologies, and image processing technologies. Sensors enable the measurement of soil and air temperatures, aiding in more informed and accurate practices like irrigation and pesticide application. Robots can take over tasks from agricultural workers, conducting harvesting operations, while robotic arms integrated into agricultural machinery can perform tasks such as plant harvesting, pruning, and spraying. Artificial intelligence has extensive applications in the agricultural sector. The method known as precision farming involves the collection and analysis of field data through sensors and drones to optimize agricultural processes. Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasing. AI facilitates the early detection of agricultural issues, such as plant diseases and pests, optimizing intervention processes for farmers. AI technology allows for more comprehensive studies on plant genetics and productivity and has increasing potential for use in processes such as the storage and distribution of agricultural products. This potential can aid in reducing food waste and improving food security (Asgen Agriculture, 2021).

## Digital agriculture

Digital agriculture refers to the tools that collect, store, analyze, and transmit electronic data and information throughout agricultural processes. These data are gathered sometimes through sensors and other times via cutting-edge technologies such as satellites and drones. Digital agriculture is a comprehensive concept that, leveraging technological capabilities, provides real-time information to farmers on aspects like planting and harvesting timing, dynamic agricultural processes, weather forecasts, soil quality, required labor, and costs (Argenova, 2022; Imecemobil, 2021).

### Advantages of digital agriculture

Digital agriculture encompasses tools that electronically collect, store, analyze, and deliver data or information throughout the agricultural cycle. Information is gathered through sensors or modern technologies like satellites and drones. It's a broad concept that provides real-time information to farmers regarding timing of planting and harvesting, dynamic agricultural processes, weather forecasts, soil quality, required labor, and costs through technological means. The benefits of digital agriculture include the following (Argenova, 2022; Asgen Agriculture, 2023; Imecemobil, 2021).

1. Increased Productivity: Digital agriculture enables farmers to achieve higher yields by better understanding soil and weather conditions through data analysis, thus increasing the likelihood of planting and harvesting the right crops at the right time (Asgen Agriculture, 2023).
2. Sustainability: Digital agriculture can aid in more efficient resource utilization, reducing unnecessary use of resources like pesticides, water, and fertilizers, minimizing environmental impact (Asgen Agriculture, 2023).
3. Disease and Pest Management: Early detection of plant diseases and pests using sensors and cameras allows for more effective control methods (Asgen Agriculture, 2023).
4. Marketing and Trade: Digital agriculture streamlines the marketing and distribution of products, enabling farmers to respond to demands more swiftly and reach broader markets (Asgen Agriculture, 2023).
5. Work Safety and Comfort: Automation and autonomous machinery can enhance farmer safety and ease the burden of laborious tasks (Asgen Agriculture, 2023)."

### Technologies in digital agriculture

Among the technologies that support digital farming are tools such as sensors, satellite data, data analysis, Internet of Things (IoT), and Machine Learning. These smart technologies aid in enhancing productivity in agricultural fields, conducting soil analysis, monitoring plant health, utilizing smart irrigation methods, managing fertilizers, and detecting pests and diseases. Digital farming refers to the tools that electronically collect, store, analyze, and transmit data or information throughout the agricultural process. This farming method, using technological capabilities, provides farmers with real-time information in advance regarding the timing of planting and harvesting in fields, dynamic agricultural processes, weather forecasts, soil quality, required workforce, and costs. Digital farming applications benefit from technologies such as sensors, satellite data, data analysis, Internet of Things (IoT), and Machine Learning. These intelligent technologies can be used to enhance productivity in agricultural settings, perform soil analysis, monitor plant health, employ smart irrigation techniques, manage fertilizers, and identify pests and diseases (Argenova, 2022; Imecemobil, 2022).

The modern agricultural systems, also known as digital farming, constitute a vast field where drones and advanced innovations are integrated into a single system to offer farmers and other stakeholders the opportunity to enhance their production in agriculture. It provides a platform for producers to make more informed decisions about agricultural enterprise systems. Smart agriculture 4.0 also involves Decision Support Systems (DDS) that promote the optimization of inputs for the entire farm, facilitating optimal use and conservation of resources needed for reduction, thereby encouraging target optimization. DDS can be utilized in almost every stage of operations related to management and administration, typically serving middle and upper-level management, aiming to extract valuable data from uncertain information primarily at the decision-making stage (Jayaraman, et al., 2016).

Agriculture 4.0 is defined as a system comprised of drones, robotics, vertical farming, artificial intelligence, the internet, and solar energy. The development of Agriculture 4.0 is based on the challenges of meeting the needs of the world's population with adequate food production (Jones & Pimdee, 2017). While Agriculture 4.0 applications often remain a barrier in developing countries, they are currently viewed as a solution to ongoing environmental, economic, and social issues (Yahya, 2018). Through smart agriculture, farmers will minimize the use of water, fertilizers, or agricultural chemicals, strengthening economies of scale and increasing profits across various farms, leading to lesser damage. According to significant reports related to Agriculture 4.0, farms and companies will be operated using advanced technologies such as sensors, devices, and machines. Most importantly, sophisticated technologies will be employed in the future to monitor soil moisture levels and temperatures in agriculture (Weltzien, 2016). It is anticipated that Agriculture 4.0 will enhance the high technology in agriculture and, thereby, promote the success of sustainable crop production (Kuo, 2015).

## Ways of using sensors in agriculture

Sensors are utilized in agriculture for various purposes. For instance, pH sensors help enhance crop productivity by measuring nutrient levels in the soil. Temperature and humidity sensors play a role in creating an optimal environment for healthy plant growth. Additionally, these sensors can be employed in the storage process of agricultural produce. GPS sensors are used to track the locations of animals, enabling more effective monitoring of their health status. Agricultural sensors can effectively contribute to different areas such as improving productivity, conducting soil analysis, observing plant health, utilizing smart irrigation systems, managing fertilizers, and detecting pests and diseases in agricultural fields (Agriculture sensors,2020; Sensors in agriculture,2021; Steeneken, P.G., Kaiser, E., Verbiest, G.J. et al.,2023).

## Autonomous Systems in Agriculture and Their Importance

Autonomous technologies in the agricultural sector are systems used to automate agricultural machinery and processes. These systems enable automatic operation of farming machinery, reducing the workload for farmers and enhancing efficiency. For instance, autonomous tractors can replace human labor by performing harvesting tasks. Similarly, robotic arms integrated into agricultural machinery can conduct activities like crop harvesting, pruning, and pesticide application. Autonomous systems improve workforce efficiency in agriculture, lightening the load for farmers. Moreover, these systems enhance productivity in agriculture while aiding in the more effective utilization of resources, contributing as a factor for sustainability in the agricultural sector (World Economic Forum,2022;Koch,2023; Autonomous farm tractors,2021).

## Technologies in Autonomous Agricultural Machinery

Autonomous agricultural machinery integrates various technologies within the agricultural sector. These technologies include artificial intelligence, image processing, sensors, radar sensors, laser scanners, GPS sensors, machine learning, and statistical data analysis. Autonomous agricultural machines are systems used to automate agricultural processes. These systems enable farming machinery to operate automatically, reducing the workload for farmers and enhancing efficiency. For instance, autonomous tractors can replace human labor by conducting harvesting tasks. Similarly, robotic arms integrated into agricultural machinery can perform activities like crop harvesting, pruning, and pesticide application ( World Economic Forum,2022; Koch,2023; *T.C. Trakya University,2022; Autonomous farm tractors*,2021).

## Studies on Artificial Intelligence Applications in Agriculture

Artificial intelligence technology is extensively utilized across various domains within the agricultural sector. These encompass sensors, cameras, robots, and other devices generating large sets of data. These technologies find frequent use in feed mixing machines, milking robots, temperature and humidity measurements, feed and water consumption, facial recognition, environmental air control, determination of sleep cycles, live weight estimations, heat tracking, behavioral analysis of animals, and emotional contagion. Artificial intelligence is initiating a new era in food production within the agricultural sector, bringing about revolutionary changes. From better resource utilization to disease monitoring and weather forecasting, artificial intelligence provides powerful tools to enhance productivity, reduce environmental impact, and improve sustainability for farmers. In agriculture, artificial intelligence optimizes precision farming, enabling early detection of plant diseases and pests, thereby refining intervention processes for farmers. Furthermore, the technology facilitates broader research on plant genetics and efficiency. By enabling the early detection of agricultural issues such as plant diseases and pests, AI enhances intervention processes for farmers (Tanya,2023).

## The Advantages of Utilizing Artificial Intelligence and Robotic Technologies in Agriculture

The use of artificial intelligence and robotic technologies in the agricultural sector offers numerous benefits. Artificial intelligence assists farmers in making more precise and faster decisions in areas such as data analysis, prediction, and automation within agriculture. Additionally, it enables more efficient utilization of resources while increasing agricultural production. By contributing to the early detection of problems like plant diseases and pests, AI optimizes intervention processes for farmers. Robotic technologies, on the other hand, are employed for automating agricultural processes. These systems, through the automatic operation of agricultural machinery, alleviate the workload of farmers and enhance productivity. For instance, autonomous tractors replace human labor by conducting harvesting operations. Similarly, robotic arms integrated into agricultural machinery can perform tasks such as crop harvesting, pruning, and pesticide application. (World Economic Forum,2022;Hektaş, 2022).

Artificial intelligence (AI) and robotic technologies have the potential to enhance productivity and efficiency at every stage of the agricultural value chain, increase farmers' incomes, reduce waste while boosting farm efficiency, and enhance supply chain efficiency, transparency, and sustainable resource utilization. AI can analyze market demand, predict prices, and determine the optimal times for planting and harvesting. In agriculture, AI can assist in gathering insights, monitoring weather conditions, and recommending fertilizer and pesticide applications to explore soil health. The use of AI in agriculture can also aid in identifying diseases in plants, recognizing crop diseases and pest damage, and identifying a disease with 98% accuracy. Robotic technologies, such as autonomous tractors and robotic arms mounted on agricultural equipment, can automate tasks such as planting, harvesting, pruning, and pesticide application, reducing labor costs and increasing efficiency ( World Economic Forum,2022; Soffar, 2019).

### Agriculture 4.0 Core Technologies:

In the agricultural sector, while data utilization boasts a long history, the innovation driving the sector's digital evolution primarily resides in this domain. Additionally, the quality of information gathered at the farm level and the technologies employed to collect, store, process, manage, and distribute such data are noteworthy. Advancements in sensor technology enable farmers to monitor specific measurements in real-time, facilitating more efficient automation of robotic processes. Furthermore, computing power has become increasingly accessible and cost-effective, thereby aiding the development of new decision support tools to enhance agricultural management.

### a) Sensors

Sensors stand as one of the primary driving forces behind the IoT concept due to advancements in technologies that not only shrink their size but also make them smarter and more affordable (Ur Rehman, Abbasi, Islam, & Shaikh, 2014; Kassim & Harun, 2016). In recent years, wired and wireless sensors have been extensively utilized within the agricultural sector (Tzounis, Katsoulas, Bartzanas, & Kittas, 2017). By acquiring plant, animal, and environmental data, sensors play an indispensable role in agricultural activities, forming a crucial technology for IoT implementation in agriculture. Spatial and temporal variations that significantly impact agricultural production can generally be managed through two approaches: map-based and sensor-based methods (Zhan, Wang, & Wang, 2002). Both approaches involve stationary or mobile sensors and necessitate extensive big data collection and analysis to more efficiently utilize farm inputs, thereby leading to enhanced crop production and environmental sustainability (Mulla, 2013).

### b) Robotics

Robots' application in automating certain tasks in this sector, such as product monitoring (plant monitoring and phenotyping), planting and harvesting, water supply, targeted spraying, environmental monitoring, has increased the interest in agriculture in recent years (Fountas, Mylonas, Malounas, Rodias, Hellmann Santos, & Pekkeriet, 2020; Shamshiri, Weltzien, Hameed, Yule, Grift, Balasundram, Pitonakova, Ahmad, & Chowdhary, 2018 Roldán, del Cerro, Garzón-Ramos, Garcia-Aunon, Garzón, de León, Barrientos, 2018). Tasks like weed and pest control, disease detection, pruning, milking, and sorting are also within the realm of robotic science. While mentioning UAVs and drones in the context of remote sensing, it's important to emphasize their direct applicability in fields, performing specific agricultural tasks. Fixed robots are typically more prevalent in industrial applications; however, in the agricultural context, mobile robots can offer greater benefits. Their ability to traverse various terrain types under different landscape conditions inaccessible to ground vehicles, cover large areas, and automate agricultural tasks holds significant potential for advancing agricultural management. Figure 3 highlights UAVs' frequent mention in various agricultural applications such as yield estimation (Apolo-Apolo, Martínez-Guanter, Egea, Raja, & Pérez-Ruiz, 2020), product disease detection (Chung, Huang, Chen, Lai, Chen, & Kuo, 2016), weed recognition and mapping (Pantazi, Tamouridou, Alexandridis, Lagopodi, Kashefi, & Moshou, 2017). Additionally, UAV-integrated systems can be contemplated as a safety system for worker health, preventing health issues arising from the manual spraying of agricultural chemicals in fields (Mogili, Deepak, & B,2018). Another variant of mobile robots extensively used in the agricultural sector in recent years is UGV, designed primarily to enhance agricultural efficiency and reduce manual labor, particularly in challenging environments for humans to access. These robots participate in various agricultural tasks like field processing, soil sampling, irrigation management, precise spraying, mechanical weed clearing, and crop harvesting (Bonadies, Lefcourt, & Gadsden, 2016; Arad, et al., 2020).

### c) Internet of Things

IoT fundamentally represents the interlinking of physical and digital entities through standardized and compatible communication protocols (Shi, An, Zhao, Liu, Xia, Sun, Guo, 2019). Its integration spans across diverse sectors like healthcare, smart residences, urban development, and industrial manufacturing. Considering the imperative need for continual oversight and management of farming operations, the integration of IoT solutions into agriculture stands as a pivotal necessity (Shi, An, Zhao, Liu, Xia, Sun, & Guo, 2019; Farooq, Riaz, Abid, Umer, & Zikria, 2020). The convergence of different Agriculture 4.0 technologies with IoT manifests immense potential, promising amplified efficacy in agricultural practices, each demanding distinct prerequisites. In agricultural discourse within the realm of IoT, a spectrum of communication protocols and technologies has been deployed to align with these requisites.

### d) Cloud Computing

Commercially internet-based infrastructure, known as cloud computing, has risen to prominence by delivering hardware, infrastructure, platform, software, and storage services for a range of contemporary IoT applications. Over the last decade, cloud computing has captured considerable attention within the agricultural domain, providing (Shi, An, Zhao, Liu, Xia, Sun, & Guo, 2019): (a) economical data storage services accommodating textual, visual, video, and other agricultural data, substantially trimming storage expenses for agricultural entities; (b) sophisticated large-scale computing systems capable of converting raw data (often challenging for farmers to adeptly utilize due to technical complexities) into actionable insights, facilitating data-centric decision-making; and (c) a secure platform empowering farmers and nurturing the proliferation of diverse IoT applications tailored for agricultural purposes.

### e Data Analytics

#### e.1. Big Data (Analytics)

The advent of IoT technologies facilitated comprehensive data acquisition across every facet of the agricultural supply chain, resulting in the generation of increasingly vast datasets. However, the agricultural sector's utilization of this data remains relatively limited (Wolfert, Ge, Verdouw, & Bogaardt, 2017; Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017), overlooking a substantial opportunity for groundbreaking, data-centric innovations aimed at fostering more efficient and sustainable production and consumption practices in the long run. Within this context, big data analytics holds a pivotal role in translating data into value for agricultural and food stakeholders by efficiently collecting, processing, and visualizing extensive and intricate datasets. Literature often defines big data across five dimensions (Demchenko, Grosso, De Laat, & Membrey, 2013): volume, velocity, variety, value, and veracity. Recent studies suggest that although big data is still nascent, its impact on the landscape and structure of Agriculture 4.0 will be profound. Leveraging high-volume, multi-source real-time, and historical data for analysis, prediction, and monitoring is expected to significantly revolutionize farm management and operations, continually enhancing business models. Beyond conventional applications such as optimizing production efficiency using large historical and multi-domain datasets (e.g., temperature, precipitation) (Majumdar, Naraseeyappa, & Ankalaki, 2017), big data analytics opens avenues to address more intricate and less prevalent scenarios. For instance, it enables forecasting food availability in developing nations to tackle sustainable food security challenges, achieved through the analysis of land use and production data collected from over 13,000 farm households across 17 countries in Sub-Saharan Africa.

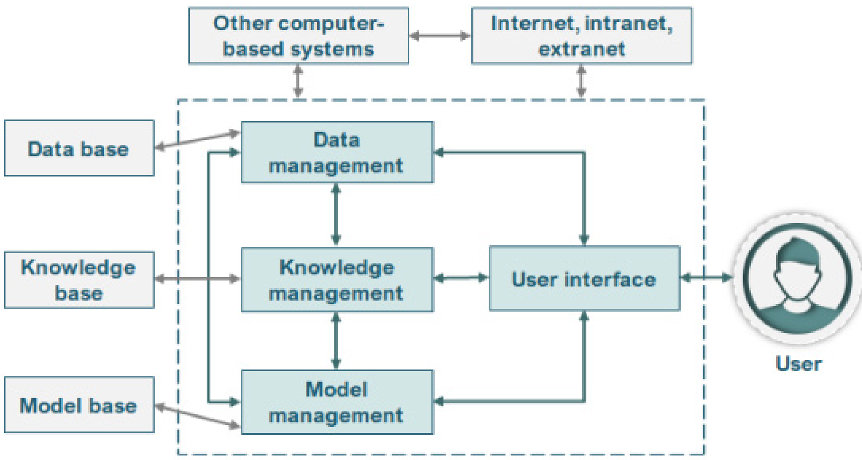
#### e.2. Artificial Intelligence and Machine Learning

Artificial Intelligence, particularly its Machine Learning facet, in conjunction with Cloud Computing and IoT, stands out as a pivotal catalyst driving the implementation of Agriculture 4.0. Recent research underscores that ML emerges as among the most auspicious techniques presently under exploration in domains such as food security, weed control, soil, crop, and livestock monitoring, as well as weather forecasting and climate shifts (Liu, Ma, Shu, Hancke, & Abu-Mahfouz, 2020; Wolfert, Ge, Verdouw, & Bogaardt, 2017; Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017). ML algorithms have been harnessed to optimize crop yield, reduce input costs by discerning intricate patterns and correlations within multidimensional, diverse agricultural data, furnish accurate predictions, and establish a robust framework for elevated agricultural decision-making and operational oversight (Shi, An, Zhao, Liu, Xia, Sun, & Guo, 2019). An updated compilation highlights that 61% of agricultural articles using ML approaches have concentrated on crop management, 19% on livestock, 10% on soil, and 10% on water management. Among the prevalent ML algorithms in the context of Agriculture 4.0 are random forests, SVMs, ANNs, and various DL iterations, notably CNNs for computer vision applications, as delineated in Figures 2 and 3. However, given the novel challenges posed by the imperative to devise scalable solutions within Agriculture 4.0, novel methodologies are emerging within the scientific community to address cybersecurity and privacy concerns in the digital era, including federated learning and privacy-preserving mechanisms. These strategies pivot on collaboratively deploying ML models across multiple nodes sans sharing sensitive private data samples, constraining the training process to local parameters exclusively (Xu, Li, Liu, Yang, & Lin, 2019). This effectively mitigates the aforementioned security and scalability apprehensions, paving a promising research path for AI within the ambit of Agriculture 4.0.

### f) Decision Support System

The concept of a Decision Support System doesn't rely on consent, but within this study's framework, a DSS represents software designed to streamline the utilization of intricate data, aiding end-users in making informed decisions efficiently. This entails converting both raw data and analytical tool outcomes into understandable information displayed through a user-friendly interface. Concerning the architecture of a DSS, Figure 1 illustrates a standard structure based on the architectural model proposed by Turban and associates (Turban, 2007).

**Figure 1.** *A decision support system typically comprises four fundamental elements: data aggregation, model development, knowledge organization, and user interface design.(Turban, 2007).*




In the Agriculture 4.0 paradigm, there is a flow of information among core technologies. Five significant stages have been identified: sensor and robotic technology encompassing sensing and application functions based on system requirements, the Internet of Things for data communication, cloud computing for data storage and processing, data analytics involving methods based on big data and artificial intelligence, and decision support systems for data visualization, recommendation functions, and user interaction.

Artificial intelligence applications stand as one of the most critical research areas in agriculture today and in the near future, offering potential solutions to streamline agricultural processes and develop alternative solutions for outstanding challenges.

The use of AI techniques in agriculture spans various domains such as crop production planning, plant classification, yield prediction, identification of plant diseases, pests, and weeds. Additionally, researchers have conducted numerous studies in determining routes for agricultural robots, making application decisions, defining greenhouse conditions, forming operational strategies, managing irrigation, crop rotation, and selecting fertilizers and machinery. Examples of AI research conducted in agriculture are provided in Table 1.

**Table 1.** *Examples of agricultural studies conducted using artificial intelligence techniques ( Terzi, Özgüven, Altaş, & Uygun, 2019).*

| Artificial Intelligence Techniques | Research Topics | Studies Conducted |
|---|---|---|
| Fuzzy Logic | Irrigation management<br>Detection of water resources<br>Determination of agricultural potential<br>Decision support system in production<br>Greenhouse systems | (Martha et al., 2016);<br>(Faridi et al., 2018);<br>(Kurniasih et al., 2018);<br>(Kale and Patil, 2018);<br>(Ali et al., 2018) |
| Artificial Neural Networks | Energy consumption in production<br>Disease classification<br>Production management<br>Agricultural waste processing | (Khoshnevisan et al., 2015); (Oppenheim and Shani, 2017); (Kamilaris & Prenafeta, 2018); (Liu et al., 2018);<br>(Khoshroo et al., 2018) |
| Genetic Algorithms | Drying process for products<br>Land use optimization<br>Prediction of soil mechanical resistance<br>Automatic land classification<br>Disease detection | (Khawas et al., 2015);<br>(Li and Parrott, 2016);<br>(Hosseini et al., 2016);<br>(Haklı ve Uğuz, 2017);<br>(Arya et al., 2018) |
| Expert Systems | Weed detection<br>Identification of greenery<br>Condition monitoring in agricultural machinery<br>System analysis in animal production<br>Land allocation | (Montalvo et al., 2013);<br>(Romeo et al., 2013);<br>(Martinez et al., 2015);<br>(Vasquez et al., 2018);<br>(Haklı ve ark., 2018) |
| Ant Algorithms | Planning agricultural contracting work<br>Irrigation management<br>Disease detection and classification<br>Soil nitrogen content estimation | (Alaiso et al., 2013);<br>(Nguyen et al., 2017);<br>(Zhang et al., 2018);<br>(Zhang et al., 2019) |

## Consequence

Ensuring economic, sustainable, and efficient agricultural production is the primary aim in agriculture. Each advancement contributes to various developments or has a facilitating effect on its own. The latest leap, Society 5.0, focuses on leveraging more effectively the impactful components such as cyber-physical systems, autonomous robots, artificial intelligence, 3D printers, cloud computing, and more offered by Industry 4.0. The goal here is to use new technologies considering the interests of society, improving living conditions, fostering social development, and achieving sustainable levels of well-being. This study aims to delve into the intersection of robotics, artificial intelligence, and agriculture, addressing the robotic tools and AI applications used in the agricultural sector. The research entails an extensive literature review on AI and robotic studies in agriculture. The utilization of robots and AI in agriculture offers advantages such as saving space and labor while enhancing quality production. Developments tied to Industry 4.0 will significantly contribute to the agricultural field. It's recommended to increase efforts in robotics applications and AI-related studies within the agricultural sector.

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