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Engineering Education Evolution

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ABSTRACT

Over the years, human needs have been subject to evolution, which translated into economic development and was the result of research, development of knowledge and technology, lifelong learning and the development of skills combined with engineering competences. The paper attempts to analyze the evolution of education with a focus on engineering in the context of the development of technology over the years in conjunction with the significant achievements of technology and engineering craftsmanship. As a result, conclusions were formulated regarding the challenges in the areas of new techniques and engineering solutions that fit into the activities aimed at sustainable development and building a friendly environment for education in the field of technology.

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1 INTRODUCTION

Over the years, human needs have evolved, the satisfaction of which translated into economic development and was possible as a result of undertaken research resulting in the development of knowledge, lifelong learning, the development of technology and skills combined with engineering competences. Evolution and achievements in the field of technology have always been linked to specific engineering knowledge and practice.

Over the years, we have observed changes in the environment, lifestyle and human needs. Motivation plays an important role in human life, which is an inspiration for: acquiring and building as a result of learning through the transmission of masters (teachers), improving through practice (sometimes by trial and error), understanding, designing and building the infrastructure of the environment, proposing better than known solutions as a result of their improvement, proposing categories of new services or products and solutions. An important element of the development of civilization is access to the existing scientific and cultural heritage created by predecessors.

The paper attempts to analyse the evolution of technology development in conjunction with the significant achievements of technology and engineering craftsmanship as a result of the evolutionary approach to the educational process.

2 ENGINEERING EDUCATION EVOLUTION VS BUSINESS

Education is a complex process focused on teaching (equipping people, including robots, with specific knowledge and practice) and learning (the ability to independently acquire knowledge and practice for one's own needs) in accordance with the educational values and goals recognized in a given community and the needs necessary for performing a specific profession or developing one's own interests. The content provided in the education process and the manner of its transmission are related to the developmental phases of a person and their abilities and interests. In practice, various methods of conveying content are known, for example: activating, multifaceted teaching, focused on theory and/or practice, didactic, informational, problematic, practical activating, programmed games. Education can also be focused on various functions, for example: getting acquainted with new material, consolidating specific knowledge, assessing the level of acquisition of specific knowledge and competences.

Over the years, schools and universities, as social institutions that shape human personality, have evolved (a gradual process of change over time) (Bejan 2022), (Gidley and Hampson 2005), (Kujawinski 2010).

From the perspective of years, the following conventionally named structures can be distinguished:

1. no classes, students have a specific social and financial status, teachers have appropriate knowledge and qualifications, the individual relationship between the pupil and the teacher is important,
2. with classes (17th century), the structure is related to the age of students, education available to all social strata (democratization), teachers have the appropriate knowledge and qualifications in the field of its transmission and the necessary infrastructure,
3. traditional type (18th-19th century), a place ensuring peace and free time for learning, collective education focused on mastering the same knowledge and skills

(usually an information monologue, listening and answering), related to the age of students, program and time requirements and organizational are determined,
4. progressive type (20th century), collective education focused on flexible partner forms of cooperation (dialogue) student-teacher in conjunction with a dedicated selection of the content, development of the entire student's personality, stress-free type and individual success, taking into account expectations and cognitive needs and needs dialogue and cooperation of students,
5. contemporary (21st century), a place providing free time with the possibility of comprehensive development of the student's personality in an atmosphere of joy, collective education focused on partner management of students' activity by the teacher and individual cognitive and creative activity of students, supporting their self-development and individuality as a result of independent learning (in terms of: creativity, integration of one's own personality), independent implementation of the task, socialization as a result of dialogue and tolerance, taking into account their psychophysical properties.

Sustainable development should meet current human needs without compromising the ability to meet the needs of future generations, using access to specific resources necessary for life and operation in a safe ecosystem. Physical sustainability is significantly related to knowledge and practice and requires specific research (prior scientific inquiry) and subject technical education.

Until the end of the 20th century, it was a tradition that engineering (technical) knowledge and practice was passed on to students by masters in a long-term process. Forms of documenting knowledge and engineering practice have evolved from oral transmission recorded (remembered) in the human mind, through pictures and printed writing to digital recording. Over the years, technologies evolve, infrastructure and eco-environment change, working conditions and lifestyle change, access to various resources changes. Technology (steam engine) contributed to the mechanization of production (18th century) and the development of processes in the areas of storage, handling and processing. The invention of electricity and the assembly line (19th century) were an inspiration for further new solutions in technology and management with a focus on mass, quality and production costs as well as access to new services and products. The automation of production, the development of mechatronics and activities carried out with less human participation as a result of the use of programmable controllers with memory and computers (20th century) contributed to the significant development and progress of civilization. They were also a source of specific needs and problems and required the search for new solutions. The next step was the implementation of a wide range of information and communication technologies (21st century) in industry and the human environment, resulting in the networking of the environment, the dissemination of artificial intelligence, the presence of cyber-physical systems, digital twin systems and the autonomy of modes that are part of large complex systems.

Over the years, engineering education has also evolved at every stage of this process: from transferring knowledge to shaping skills, as well as educational techniques and technologies. Knowledge and engineering practice changes over the years and becomes outdated and is replaced with a new one or is expanded. Until recently, the knowledge necessary to perform a specific profession (profession) was precisely defined, and mathematics was identified as a way to develop creative thinking by a

person. General technical knowledge was supplemented with specialist knowledge and practice dedicated to a specific profession.

The concept of Industry 4.0, aimed at networking complex, distributed and autonomous industrial and business structures, has been translated into the need to provide staff with specific new qualifications and competences as a result of the education process. Significant areas requiring knowledge and practice in the education process were identified, in particular: acquisition, analysis and synthesis of databases and knowledge; intelligent and embedded systems; additive manufacturing; new smart materials; sustainable energy; new business models. The education process requires the acquisition of specific specialist tutoring and skills, communication in the cyber-physical system, adaptation in an environment with variable properties.

In the field of education for the needs of Industry 4.0, there are a large number of publications (Hernandez-de-Menendez et al. 2020), (Himmetoglu et al 2020), (Lewin et al. 2023), (Trevino-Elizondo and García-Reyes 2023) in which the authors present their experiences in the field of educating staff for the digital industry with the perspective of its development in a direction not fully known.

In the 21st century, there has been a significant development and access to mobile technologies and software using artificial intelligence. The new digital twin environment and the new mobile educational potential significantly affect the qualitative and quantitative evolution of education in terms of accessibility in particular and content on a global scale. It has a significant impact on the development of individuals and societies, the creation of new socially and business useful professions. Important in the education process are, among others: activities related to harmony and internal balance; sustainable development with a focus on people, the environment and resources; intergenerational, intercultural and team cooperation; skilful use of global electronic resources of knowledge and information; learning to create and transmit knowledge.

3 EDUCATION VS INTERNET OF EVERYTHING CONCEPT

Specialist chatbot applications (originally chatterbot, 1994) are now known, classified as artificial intelligence (AI) technologies (Thomas 2023), enabling dialogue with a conversation partner in natural language and simulation of interaction (text or voice) with a human as a dialogue partner. They use machine learning (ML) technologies from large amounts of data (deep learning in particular) and natural language processing (Gupta 2023), (Malik et al. 2023). In 2022, OpenAI launched a product called ChatGPT (chatbot with artificial intelligence) (Barrot 2023).

Artificial intelligence is now widely used in decision-making and robotization processes. Applications of artificial intelligence in education (Artificial Intelligence in Education, AIEd) is a new issue that requires research in the field of teacher-student interaction, as well as the use of tools related to artificial intelligence and learning outcomes (education) and areas for their effective learning. The implementation of artificial intelligence (AI) in education is a new challenge for teachers, in particular in terms of learning and understanding a new tool in the context of new applications, ethics, new interactions between users (Wang 2023). Important elements are the relationship between learning and teaching combined with understanding, critical assessment of the decision-making process and the management of mechanisms

associated with artificial intelligence and the database input necessary in the software learning process. Complex digital twin systems are being built with a focus on business applications. The designing of digital twin systems for the needs of education is to be considered. The paper (Far et al. 2023) discusses the opportunities, challenges and future directions of new generation communication in the digital system

The process of machine learning with a focus on decision-making processes in technical applications has been significantly developed since the beginning of the 21st century. The year 2020 was a breakthrough in building on-line electronic interactive connections between single isolated people using on-line type dedicated digital tools. These tools were then successfully adapted to the on-line education process, and then in hybrid mode. On-line education allows students to access the content and educational materials in a place and time convenient for them. The observed dilemma is the possibility of assessing the student's active involvement in the learning process with understanding, and then assessing the acquired skills, competences and practice. Another issue is the analysis of students' predispositions in terms of the possibility of assimilating the content transmitted by them, the possibility of increasing their ability to build innovative and practical, environmentally and economically possible solutions that fit into the concept of sustainable development.

One of the solutions for assessing the level of student involvement in the education process is remote monitoring of their physiological state using a non-invasive method of examining the bioelectrical activity of the brain using an electroencephalograph (EEG). The results of the conducted research on the assessment of student activity in the on-line education process using EEG are presented in paper (Gupta 2023). Forecasting the adaptability of students in on-line learning is possible using a modified team machine learning model, which is the subject of paper (Malik 2023).

Chatbots are now considered as a tool for learning language in a natural and human-like way interactive experience. In particular, the ChatGPT tool has the potential to edit and review documents using global electronic resources. Significant issues that require research are the credibility of the documents received, the results of decision-making processes, ethics, and other related issues, including the ability to formulate a task to be performed.

In market practice, until the end of the 20th century, the concept of corporate social responsibility CSR (Corporate Social Responsibility) was developing, focused on building common value while making profits. Since the beginning of the 21st century, the concept of joint responsibility for the environment, society and corporate governance ESG (Environmental, Social Responsibility and Corporate Governance) has been developed. The ESG concept is currently a global trend determining the directions of development of the global economy and social changes. It is part of the concept of the 2030 Agenda for Sustainable Development and the SDGs (European Commission 2018).

The business model is changing from short-term (CSR, focused on achieving the greatest possible profits here and now) to long-term (ESG, taking into account environmental and social goals) (Menghwar and Daood 2021).

Internet of Everything (IoE) is a concept of a network connection of people, processes, data and things with a focus on useful added values obtained on-line. The concept of adaptation the Internet of Things in education has been presented in paper

(Konstantinidis 2021). There is a possibility of creating artificial intelligence ((Bubeck et al 2023), (Hodson 2020), (Shevlin et al. 2019)) at the human level HLAI (Human Level Artificial Intelligence), also referred to as general artificial intelligence AGI (Artificial General Intelligence) for example by: OpenAI, DeepMind, Anthropic), obtained as a result of using an autonomous machine program meeting the Turing Test (a demonstration of the ability to use natural language and indirectly the thinking process) and having the ability to understand, learn and perform any intellectual task in a human-like manner, and then with the ability to evolve into a superintelligence.

The business model is changing from short-term (CSR, focused on achieving the greatest possible profits here and now) to long-term (ESG, taking into account environmental and social goals) (Menghwar and Daood 2021).

The role of artificial intelligence in education and research, with a discussion on the possibility of students achieving better results, is the subject of paper (Alqahtani et al. 2023). Collaborative Technical Education (CTE) approach is being developed on-line with the use of artificial intelligence. The effects of implementing CTE in practice are also being studied (Lakshmi 2023). The use of artificial intelligence in on-line education may result in, among others: greater attractiveness and effectiveness of the education process, individual adaptation of the process to the characteristics and predispositions of the student, increased access to engineering education, motivating teachers to increase the attractiveness of the content provided.

The Internet of Everything is an important platform for the development of Industry 5.0, where the boundaries between different disciplines are blurring, cyber-physical interactivity is significant, the resilience and security of the system dominates, and an approach focused on sustainable development is expected. A discussion on engineering education in the future was conducted in (Broo et al 2022).

Requirements for students by business include: knowledge of foreign languages, solid knowledge in the field of technical sciences, knowledge of current trends in technology, practical skills, soft skills, professional experience, knowledge of new innovative technologies, preparation for international and local cooperation in the field of knowledge and experience exchange. Universities should adapt their curricula to the needs of future employers and the challenges faced by graduates of higher education.

It seems that an approach focused on shaping in the educational process is currently expected (Tadeusiewicz 2000):

1. skills in the field of: constant learning, assimilation of specific data and knowledge by memory and practice for the needs of action in critical situations, the ability to search for specific data and knowledge from resources available in traditional and digital forms, the ability to select the information obtained with a practical focus on a specific goal (need), the ability to use the accumulated own and supplemented knowledge and practice,
2. the ability to critically evaluate content in terms of acquired data and knowledge,
3. methodologies for obtaining and transferring data and knowledge: the Internet as a source of targeted knowledge and data, ICT tools, specialized intelligent robots vs. human beings as a source of data and knowledge.

4 SEFI CONFERENCES VS SENSITIVITY IN ENGINEERING EDUCATION

An example of the sensitivity of the academic community in the field of engineering education are SEFI conferences, which have been held regularly since 1973. The issues raised by the SEFI environment at thematic conferences focused on education were in line with the period of production automation and information and communication technologies, as well as issues focused on sustainable development. Over the years, the question of how to educate engineers prepared for the new complex world of the future has evolved. The questions concerned the model of the engineer of the future and reflection on the role of engineering education for global economies, especially in the context of the concept of sustainable development.

The achievements of the 50 editions of the SEFI Annual Conferences (1973-2022) are focused on engineering education, exchange of views and meetings with educators (mentors, students) and building a European network of contacts (SEFI 1973-2022).

The topics of the conferences were diverse and dealt with current issues in the environment, including in the areas of: Methodology of education in the field of technology; Assessment of the quality of engineering education; Shaping non-technical skills among engineers; The essence of engineering design (1974, 1990); Undertaking technology-oriented research in educational institutions; Continuing education of engineers; Entrepreneurship, management and engineering education; Education of engineers for innovative processes; Professional requirements in the field of technology; Interdisciplinarity and international cooperation in engineering education; Global engineer; Cooperation of industry with engineering universities; The importance of an engineer in a changing world; Engineering education with a focus on lifelong learning; Diversity in engineering education; The impact of information technology on engineering education; Humanities and arts in sustainable engineering education; Creativity, innovation and entrepreneurship for excellence; Blended learning in engineering education.

The 2023 edition of the cyclical SEFI conference is aimed at the next stage of the evolution of engineering education closely related to technology in terms of sustainable development in the global dimension.

5 EDUCATION VS DEMOGRAPHIC CHANGES

In the area of profession and education (also in the lifelong formula), we distinguish the Y and Z generations (Betz 2019). There is a strong correlation and qualitative impact of the previous generation on the next generation.

Generation Y is interested in environmental problems, engages in activities supporting the rational use of Earth's resources and environmental protection, and consumer decisions are well thought out and balanced. He actively uses social media. Generation Z having the ability to use the technology of the real and digital worlds simultaneously, prefers a lifestyle focused on ensuring work-life balance, learns for specific current needs (just in time learning) without a vision and the need for long-term building professional career.

The proposed forms of education should be adapted to the needs of specific generational groups.

6 FINAL REMARKS

In the statement have been characterized the evolution of the education process, in particular in the field of technology, against the background of development and new needs of the industry in the so-called hard areas (technology and related), soft areas (communication, software, management, decision-making, evolution, ethics, resilience), accessibility specific resources and taking into account demographic changes. It is important to shape new relationships between the teacher and the student aimed at triggering innovation and creativity in a dynamically changing environment focused on sustainable development.

The world is changing, the business model is changing, we are changing individually, so the education in engineering process must also evaluate in terms of content and form. An important challenge for the educators community is to notice and react to the demographic changes that are taking place, which are natural generational changes in the life cycle, including in the field of engineering education, professional activity, lifestyle and others. We watched the wonderful original form of the new type of invitation to the next edition of the SEFI Annual Conference 2023 (synchronized sound with the image and mimedramas as a form of communication) in Barcelona in 2022. The engineering education process in a systemic and interdisciplinary approach significantly affects the characteristics of a person, his needs, lifestyle, work ethic, responsibility and other values.

Sustainable development (eco-development) means a new philosophy of global, regional and local development, opposing narrowly understood targeted economic growth, as well as engineering education.

The 50-year achievements of the successive editions of the SEFI conferences indicate the sensitivity of the environment of educators in the field of technical sciences (engineering, technology) to demographic changes and changes taking place in the business environment, in particular in Europe. Tools and methods were sought, with the use of which it was possible to qualitatively improve the engineering educational processes. A European education ecosystem in the field of technical sciences was built, in which good practices were promoted. The analysis of this achievements allows to clearly state that the environment has a significant potential in terms of adaptation to dynamic changes in business and the environment, as well as the ability to formulate current topics of debates.

General engineering education and upbringing have an anthropological, cultural and civilization dimension. They are among the most significant factors of change and creative transformation of man, culture and civilization through the development of technology. Engineering education is one of the most important factors shaping the future of every civilization and ensuring development in science and technology. At the same time, in the education process, our sensitivity to new needs and challenges resulting from the ongoing changes is shaped.

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