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# THE ROLE OF STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) EDUCATION IN THE DEVELOPMENT OF CIVIL ENGINEERING SKILLS.

"The leaders of the future will be those who understand the dynamic ecological, technical, and socio-economic systems that shape our world." - David J. Odeh is a Principal at Odeh Engineers, Inc., a leading structural engineering consulting firm with offices in Providence and Boston [1].

Science, Technology, Engineering, and Mathematics (STEM) have combined being a force of inspiration and constant progress since the emergence of the human mind and the formation of human civilization [2]. In the early 1990s, the acronym STEM was used by teachers in science and engineering education. At the suggestion of Dr. Rita Colwell, in 2001, the U. S. National Science Foundation proposed that scientists and teachers use the acronym STEM to combine the academic disciplines of science, technology, engineering, and mathematics [3]. This term is used to develop national education programs and has meaning for expanding the labor market and national security.

The innovation process is accelerating throughout the world, and with it, competition in world markets for scientific and technical talents. The shortage of specialists with education in STEM fields directly affects the efficiency of the state's economy. Thus, the innovation potential, prosperity, and security of a nation depend on the effectiveness of the STEM education ecosystem. There is no consensus on which academic disciplines are included in STEM. For example, the United States includes social sciences as STEM, while the UK classifies social sciences separately. Following the recommendations of the US National Science Foundation, the academic discipline of Civil Engineering is a fundamental component of STEM education [4].

As previously noted, the economy is directly dependent on the STEM literacy of the population. In a world of rapid development of complex technologies, the consumer is already required everywhere to be able to use digital devices and have STEM skills, ranging from controlling a microwave oven to writing scripts of programming codes. With the evolution of STEM education, following the development of complex technologies, there was a need for a more integrated and interdisciplinary approach in the organization

of the construction process and the design of civil and industrial infrastructure facilities. As an example of this approach, we can cite a mathematical model for calculating the forecast of formaldehyde concentrations over highways in Kyiv city's example [5]. This model calculates and simulates the pollution zone spatial interpretation using ArcGIS tools.

Yesterday, it seemed like engineers switched from a drawing board to CAD programs. But already, at present, 3D design is a standard and a mandatory requirement for design documentation in many countries. Since STEM includes computer science, a modern Civil Engineer should have the knowledge and ability to design and organize construction products and read and write program code. Autodesk's Revit CAD software product, widely known in the construction industry, requires a modern engineer's knowledge of the program code. For example, Python program code allows you to create scripts on the Dynamo visual programming platform for designers with subsequent integration into Revit. This allows the engineer to go beyond the basic functionality of the Autodesk Revit product. As a result, for example, a designer can process the data of thousands of measurements with dozens of parameters within a few minutes instead of 2 or more weeks of continuous work in "manual" mode.

The collection, processing, and analysis of data (Data Science) is another concept that every modern engineer hears and encounters everywhere in today's world. For example, as laser scanners improve and become available, a handheld scanner can replace an engineer's standard tape measure. In the Leica product line, such handheld models of laser scanners as BLK2GO, BLK360, BLK ARC, BLK2FLY, and the size of a conventional BLK3D smartphone are already available to the engineer today. This makes it possible to collect data on measurements of infrastructure facilities and terrain and create digital clouds from tens of millions of points both from the ground and from the air in minutes. The collected data themselves are of no practical use without the ability to process, integrate, and use them together with other software products for design, such as Register 360, Cyclone 3DR from Leica, or ReCap Pro Revit from Autodesk.

Another example of the demand for STEM skills for an engineer is the ability to use IoT (Internet of Things) technologies in construction work, the operation of buildings and utilities, and designing and creating smart cities. Today, an engineer does not need to be a high-end electronics or software expert for IoT applications. Due to the existence of single-board computer modules such as Raspberry, Arduino, Particle, plug-in sensors, and sensors (the range is widely represented https://www.seeedstudio.com), platforms data storage and processing Google Cloud Platform, Microsoft Azure, InfluxData, QuestDB, an engineer can assemble a technological IoT solution

from such ready-made modules in a few hours.

As a practical application of IoT (Internet of Things) technology in the planning and operation of urban infrastructure, Figure 1 presents a scheme for automating stormwater management based on cloud products of OPTIRTC, Inc. [6].

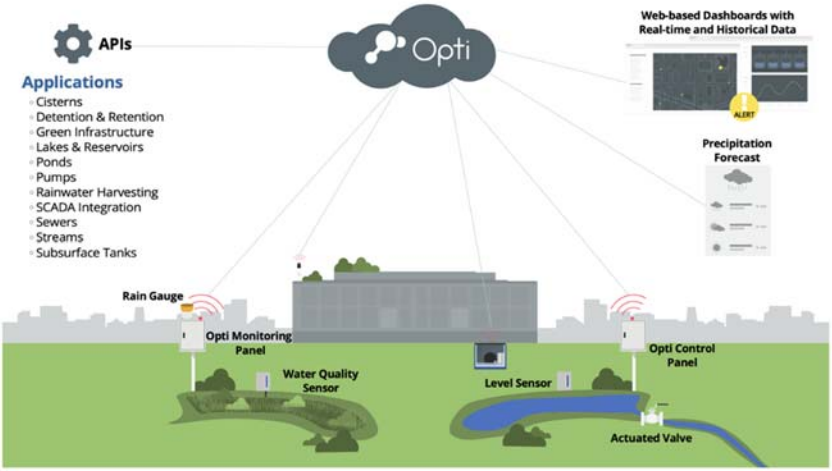


Figure 1. Schematic diagram. Information is integrated from field-deployed environmental and water-level sensors, actuated valves, telemetry-enabled control panels with cloud-based control systems, and real-time weather forecast to data monitor performance directly and actively control stormwater storage and flows. Figure from Atkins. Right of use graphic assets granted by OPTIRTC, Inc.

Another practical example of IoT (Internet of Things) technologies is creating a real-time monitoring network for air quality (concentrations of construction dust and other solid particles) on and around the construction site. This is especially important when carrying out construction work in conditions of close urban development and near existing residential complexes. The construction manager, receiving notifications of exceeding the acceptable norms, can take timely measures before a real threat to the health of construction site workers and residents of nearby residential areas arises. An integrated approach to design when using laser scanning and automated data processing technologies provides opportunities to use IoT and AI technologies to eliminate natural and manufactured disasters. And modeling artificial events using such technologies offers opportunities to

prevent such tragedies, where time, every minute, is crucial for saving the population's lives and protecting the environment.

The brief arguments provided here allow us to assert that a modern Civil Engineer with knowledge of STEM represents a group of national interests for any state and humanity. Therefore, it is essential to constantly develop new and improve existing STEM education approaches and teach academic concepts through their application in the real world in practice. Particular attention should be paid to formal and non-formal education already at the stage of school education since school education provides the necessary prerequisites for professional technical training at an advanced level at a college or university. Such methods will allow the future specialist to develop critical thinking and the ability to solve problems and skills of cooperation and adaptability.

Increasing digital literacy and improving the staffing of specialists with STEM knowledge will have a positive effect on the economies of all sectors of human activity. Therefore, it is essential to consider the above arguments in favor of STEM education as part of the development of training programs. And also, to provide equality and accessibility to such education, scientific achievements, practice, and the involvement of the population in STEM education.

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