The Internet of Things in Transport Technology Improvement and Project Learning

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Abstract. A fairly new field of science and technology - the Internet of Things (IoT) and Industrial Internet of Things (IIoT) are considered in relation to the development and digital transformation of the transport industry and higher education. At the same time, the influence of this technology on both transport processes and transport education is presented. An example of the industrial Internet of things use in the development of a package product ‘smart container-transformer’ and an exhibition complex for presenting this product is given. The means and results of the project-based learning implementation based on the Internet of Things in the course of teaching the discipline ‘Transport systems’ among graduate students are presented.

1. Introduction
Today, we can regretfully state that a fairly large number of technical specialists and teachers of technical universities are not familiar with such concepts as the Internet of Things (IoT) and Industrial Internet of Things (IIoT). However, the Internet of Things is one of the main trends in technology development. The world’s leading industrial and IT companies work in this direction.

It is of no secret that the Russian economy has been heavily dependent on energy prices for several decades. At the same time, there is a decline in production in all industries. Not to mention the extremely small number of new technologies being developed and introduced into production. In order to change the situation, it is necessary to track and apply the global development trends. However, this requires technicians who are aware of these trends, and who also know how to find the new development opportunities and apply them. The emergence of a sufficiently large number of such technical specialists is impossible without the educational system transformation in universities, especially at the second stage of obtaining higher education - in the programs for Master’s degree.

Today, many actions that previously could only be done by a person are performed by robots, and what previously could only be done on our own, it has become possible to perform online. For example, ordering food online, paying bills, and so on. If these capabilities of automated subjects are combined with the capabilities of Internet networks, then this is a simplified concept of the Internet of Things.

The idea of the Internet of Things was born in 1999 [1]. Kevin Ashton from the Massachusetts Institute of Technology put forward the idea of automating the management of the supply of goods to the warehouse at his presentation. If to combine all warehouse terminals into one network, then it will be possible to regulate many issues without the participation of people. For example, if the warehouse runs out of some product, then the machines could figure out what is missing and also order replenishment on their own. The concept is dubbed the ‘Internet of Things’. The idea is based on the
use of ordinary things in human life, but not as static objects, but as things that can analyze the environment and make the appropriate decisions. Almost any thing can be done smart no matter the application area is, and the new IPv6 protocol makes it possible to assign a network address to absolutely every ‘smart’ thing.

Modern technology is inevitably changing the education concept. Now the information accessibility level is such that a person with a certain educational base, but without special education, is able to master quite complex technologies at a practically significant level in the shortest possible time, for example, programming microcontrollers and creating ‘smart’ things on this basis. However, to create a base that will enable the bulk of specialists to use the information products, it is necessary to rebuild the education system. This requires radical transformations and is fraught with certain problems.

2. The problem analysis
The problem of introducing the Internet of Things into the economy and higher education needs to be analyzed from different points of view. On the one hand, there are technical and economic complexities. On the other hand, there are the problems of modern pedagogy and higher education. Let us analyze these problems.

2.1. Analysis of publications on this issue
At the moment, there is a fairly large number of studies and publications on the IoT topic. A group of scientists from Croatia, Spain and Italy [2] have made a detailed survey study reflecting the development of the Internet of Things at the moment. The study divides the direction of IoT development into developments in the field of energy, the creation of smart cities, healthcare and transportation. That is, the relevance of the transport topic from the point of view of the Internet of Things is confirmed by other studies.

The publication [2] also noted that an obstacle to the development of the Internet of Things in Africa, Latin America and some countries in the Middle East is the low speed of Internet networks.

The authors of [2] also considered an issue that is usually not thought about: the expenditure of the production resources for IoT products, as well as the subsequent disposal of products that have expired. It is suggested that resources and minerals may not be enough at the current pace of IoT devices’ development. However, it is noted that the IoT technologies’ growth is associated with the growth of the world’s population, urbanization and resource scarcity. Growth is driven by the need to improve urban infrastructure.

IoT development is also taking place in the field of improving the environmental friendliness and autonomy of road transport. Smart cars learn to do without a person in matters of traffic control, registration for maintenance, diagnoses when diagnosing faults, finding parking, active and post-crash safety as well as many other options.

A group of Polish and American authors presented the support system development for public transport passengers based on IoT technologies [3]. The publication highlights the development of a new model BIBO (Be-In / Be-Out), which allows, based on IoT devices (smart beacons and smartphones), to automatically pay for travel during the trip without the participation of a passenger. Self-learning models of passenger identification in transport were applied based on the statistical models and neural networks. According to the authors, in this case, the statistical models work better.

A group of Indian authors published [4] the information on the developed system for ensuring the passengers’ safety on buses in case of emergency situations. It is proposed to equip buses with an intelligent system equipped with a set of sensors for the occurrence of various emergency situations (fire, increased vibration on wheels, over-speeding). The sensors send a signal to the microcontroller, which sends information to the data cloud and issues the commands to security systems. These can be the signals to alert the driver, passengers, a command to stop the engine by cutting off the fuel supply, opening emergency exits after stopping and starting the fire extinguishing system. In the event of an emergency, a signal will be sent to the rescue services automatically via GSM networks, accompanied by detailed information about the incident.
Other authors from India presented [5] the concept of an intelligent system for fast parking space search. This problem is especially acute in large cities and metropolitan areas around the world. The biggest difficulties arise when trying to find a parking space during business hours. As a result, a huge amount of time is spent searching for empty seats, while huge amounts of fuel are burned and large amounts of exhaust gases are emitted. The researchers proposed an IoT system that includes ultrasonic sensors for monitoring parking spaces, analog-to-digital converters based on Arduino microcontrollers, a cloud database and a Raspberry Pi-based processor. To track free parking spaces where it is not possible to install ultrasonic sensors, it was proposed to use quadcopters with video cameras. In the future, it is proposed to expand the project based on the tactile Internet and 5G networks new technology.

The authors from Malaysia, the United Kingdom and the United States [6] propose an integrated system for transport management, data collection and decision-making based on all existing IoT applications: radio frequency identification, Bluetooth and WiFi-based networks, vehicle communication networks, 4G standards and 4G, wireless sensors and cloud technologies. Combining the capabilities of these technologies into an IoT system, according to the authors, will improve the safety, economy and production efficiency of vehicles.

The analysis of publications on the topic of industrial technological development, including road transport, developing in the direction of IoT technology, makes it possible to conclude that this new technology is being actively implemented, but it still has a very large potential for further development. Accordingly, there is a need for training specialists of a wide variety of profiles who have the skills to use IoT in their professional activities.

The authors from Australia published a paper [7] devoted to the IoT introduction in the educational process in training specialists in the field of agriculture. In the course of the study, an analysis of the IoT electronics available on the market, services for the databases and data exchange formation for IoT purposes was carried out. As a result, the optimal microcontrollers and sensors were selected, and free, but highly efficient resources were chosen as the means of accumulating and processing information. As a result, a system for visualizing environmental parameters within an agricultural farm was created. This system is introduced into the educational process, and the concept of problem learning is implemented on it. The authors noted the lack of educational literature and methods for introducing IoT into the educational process of universities.

During the literature search, it was not possible to obtain the information about the implementation of IoT systems in the educational process of training transport areas. Therefore, the pedagogical developments in the field of IoT systems presented in this article are relevant and are designed to fill the existing gap.

2.2. Analysis of the problems in higher education

The author of this article has over 15 years of experience in teaching in higher education. During this time, educational standards have changed, the Bologna system of higher education (bachelor, master) was adopted, and a student-oriented competence-based approach to learning was proclaimed. However, in essence, these processes were carried out on the basis of the remnants of the Soviet education system, and inherited many of the shortcomings of this educational model. People who continue to lead the educational process often do not understand the essence of the transformations being carried out, and they follow them exclusively when preparing documentation. The educational process itself remains unchanged. Controlling structures are also interested, first of all, in properly formatted documentation.

Let us consider the shortcomings of the existing education system:

- Weak interdisciplinary communication. Most disciplines are studied by sporadically, especially in general education and general technical disciplines.
- Excessive overload of theoretical calculations. Often a teacher, especially the one who has been leading the discipline for many years and has learned the material well, gives students a huge number of long formulas, diagrams and graphs. And he sees the learning process as a thorough memorization of the material given out, and then - the reproduction of what was learned for the exam.
- Lack of many disciplines' connection to the professional field of graduates.
It should be noted that 15-20 years ago, these teaching methods were perceived by the students back as inevitable hardships of the process of obtaining higher education. Many students memorized the material without thinking about the meaning of this process, passed it successfully, and soon forgot it. Today’s generation of students is more pragmatic and such methods stop working. It is difficult to force a student to learn the material if he does not understand why it is needed.

We live in the information age, when access to a wide variety of knowledge can be obtained with a mouse click. But the information availability does not replace education, as many students believe. But memorizing formulas and definitions without thinking is not the way to get an education in the modern world. If earlier it was believed that a teacher in a discipline should know everything, then in the information age he should not and cannot do it. The task of the teacher is to teach how to search, screen out, analyze and apply the available information, to help students acquire skills and abilities in the professional sphere. Modern education is based on project activities that are part of the project-based learning system [8].

Despite the fact that project-based learning has been known for more than 100 years, in the information age it has only increased its relevance [9, 10]. For the employer, it does not matter what a university graduate knows, it is much more important what he knows how to do and if he knows how to master new skills on the basis of his existing educational base. such Modern technologies as IoT have given the learning opportunities of a higher order.

3. Development of IoT products and project learning methods based on them

3.1. Smart transformer container and educational and exhibition complex

Let us consider the ‘SmartBoxCity’ [11] project, in the course of which the ‘Internet of Things’ technology was applied. At the same time, both an industrial IoT product and an educational and exhibition complex, consisting of operating car models with a manipulator and reduced-size transforming containers, were obtained. The author of this article is a member of the project team and the direct developer of the remote-control system for the educational and exhibition complex.

‘SmartBoxCity’ is an innovative IoT package product for container shipping that consists of:

- Hardware - a smart transformer container (Figure 1), equipped with sensors for cargo weight, temperature, humidity, light, inclination, impact, video cameras for monitoring cargo online, a mechanism for folding and unfolding, raising and lowering doors and side walls (Figure 2, Figure 3), batteries and solar panels.
- Software part - server software, data cloud, website, mobile user and driver applications, API integration of the Yandex.Routing system for managing the transport process logistics.

Figure 1. Unfolded transforming container.  
Figure 2. Convertible container in the process of folding.
The ‘SmartBoxCity’ package product gives an opportunity to transport packaged cargo, as well as bulk cargo using ‘flexy tank’ flexible containers. The system is currently designed for the transport of goods in an urban environment. However, the design and technology can be transferred to the containers of any size and purpose. Folding, unfolding, formation of an order for transportation, acceptance of the order by the car driver with a manipulator and tracking the progress of the transport process occurs from a smartphone via a mobile application.
To obtain the opportunities to demonstrate the development functionality in rooms and on a small area, as well as for educational process use in the university, an educational and exhibition complex was developed and produced. It consists of a manipulator with a telescopic trailer (Figure 4, Figure 5) mounted on an electric vehicle and two fully functional miniature convertible containers (Figure 6, Figure 7). The manipulator and container drives are based on linear actuators powered by 12 V lithium-polymer batteries.

Let us consider the electronic circuit of power supply and control of the educational and exhibition complex using the example of the container-transformer exhibition layout, which is shown in Figure 8. The linear actuator (not visible in Figure 8, as it is located in the bottom of the container) is powered by battery 1. It is connected through the connectors 2 to the electromagnetic relay 3, which performs the function of switching the polarity of the supply on the linear actuator. The function of a load weight strain gauge, a GPS sensor, as well as the container software is performed by a simulator program built into a smartphone 4.

Figure 6. Unfolding the container layout.  
Figure 7. Unfolded container layout.  
Figure 8. Electronic circuit of power supply and control of the transformer container exhibition layout.
To ensure the possibility of correcting the connection diagram without soldering, a prototype board 5 was used. It has a microcontroller 5 of the ESP32 model with a built-in Wi-Fi antenna and a Bluetooth adapter that controls relay 3 depending on the commands sent from the smartphone. The power supply for the control system is separated from the power section and is supplied through the power bank 7, which simulates a solar battery. The microcontroller 6 is connected to humidity and temperature sensors 8 and light inside the container 9 to check the tightness of the door closing. Sensor data is sent to the server and then transferred from the server to the simulated smartphone, as well as to the main container management tracking application.

Management of the educational and exhibition complex is implemented in two ways: via Wi-Fi using the MQTT Internet of Things protocol via a free account of the MQTT broker Cloudmqtt and via Bluetooth via a free terminal application Dabble.

The educational and exhibition complex will be used in the process of training bachelors and masters of transport training areas of the Don State Technical University.

3.2. IoT-based project learning

The simplicity of the IoT technology electronic systems used to equip the educational and exhibition complex of the ‘SmartBoxCity’ project and the ease of mastering the programming of microcontrollers in the Arduino IDE based on numerous templates from the Internet allows creating a variety of projects, including in the field of transport. This was the basis for the introduction of project training in the Master’s program ‘Technology of transport processes’ among the students.

In practical classes, the students were introduced to the IoT technology essence and demonstrated the possibilities and simplicity of creating smart devices based on the ESP32 microcontroller. This microcontroller has a built-in timer, Hall sensor, analog-to-digital converter for connecting analog sensors, built-in WiFi and Bluetooth, 36 pins, 18 of which are available for creating projects. The microcontroller is equipped with a dual-core processor.

The students were asked to familiarize themselves with the variety of devices and sensors that can be used with the ESP32. An overview of the main models of microcontrollers on the market was also given, with an analysis of the advantages and disadvantages.

Each graduate student has a Master’s thesis topic that they must defend in order to obtain a Master’s degree. The students are encouraged to develop a small IoT project connected with the dissertation topic. An IoT project is carried out in the form of a business plan, which should contain:

- Description of the IoT project essence with the disclosure of scientific novelty and practical value.
- Comparison with analogues.
- Description of the design, structure, software and hardware components of the project.
- Assessment of the potential sales market and areas of implementation.
- Assessment of economic efficiency and payback periods.

Project-based learning based on IoT technologies solves the problems of modern higher education described above:

- Knowledge from a variety of disciplines is actively applied, interdisciplinary connections are used.
- Students study the material of various disciplines from the point of view of practical applicability, and the mathematical apparatus is used as a tool for finding the IoT project parameters.
- The acquired skills and design results are used in the course of writing a Master’s thesis and can be a part of professional activity. Students are encouraged to submit the projects for participation in competitions and grants.

In project-based learning, the student acquires many practical skills. Some projects contain elements that go far beyond the direction of student training (applied programming, electronics, etc.). In this case, it is recommended to involve students in specialized areas of training and organize teamwork. Organizing and managing a team is also a critical professional skill that project learning can provide.
4. Summary
The purpose of introducing IoT technologies into transport technologies and the educational process is to raise the technology level of any technical specialists to a new world level. ‘Smart’ technology makes life easier for users and gives new economic opportunities. However, it requires highly qualified personnel in a variety of specialties. Thus, such new technologies as IoT, are a factor in the need to transform the education system. On the other hand, they provide opportunities for such transformations, such as IoT-based project learning. It is planned to extend the experience of the Master’s program to the Bachelor degree students as project training development, and then to establish a mechanism for organizing teamwork with the involvement of students in specialized training areas and the subsequent nomination of educational projects for competitions and grants.

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