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Application of Prototyping Microprocessor Board and Cloud System to Teach Industry 4.0 Concepts*

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The Industry 4.0 has become an important concept as well as direction in the industrial and social development. In the core of this new shift is implementation of new technologies that open a number of important issues, starting from managing complexity of the systems, up to new educational and training needs for students and employees. In this paper we will preset usage of microprocessor boards and cloud systems in engineering education. The given example will be presented using NodeMCU card, sensors and ThingSpeak cloud system, as well as, Virtuino for communication and data presentation. In addition, application in undergraduate courses, educational tasks, and student's satisfaction will be presented.

Keywords: education for industry 4.0; prototyping microprocessor boards; cloud systems; NodeMCU; Virtuino; ThingSpeak

1. Introduction

Although there is no strict definition of the term Industry 4.0 (I4.0), it generally refers to a transformation of the global industry, driven by ongoing technological advances. On the other hand, it is clear that all underlying concepts are affected with the shift toward Industry 4.0: Quality 4.0 [1], Maintenance 4.0 [2], Safety 4.0 [3], Operator 4.0 [4], Cyber-security 4.0 [5], Logistics 4.0 [6], or influences and connections with Supply Chain Management (SCM), Lean [7].

In the core of all I4.0 branches is the adaptation of innovative technologies, mainly Information and Communication Technologies (ICT), through [8]: digitalization and integration of all product life cycle phases [9]; monitoring and control of physical systems and processes [10]; networking of machines, machines and employees, as well as customers and suppliers [11, 12]; simulation, modeling and virtualization of design and production processes [13]; sensing, acquisition and analysis of big data through cloud systems [14]. The transition to Industry 4.0 will take time and it will face different challenges, such as dealing with the complexity of the systems, possible high financial costs and the lack of qualified employees [15]. The need for special qualification, as well as for a new employees' knowledge will change many different professions, but the most affected will be engineering education [16], and beside this economy branch under the greatest influence will be agriculture, transportation, and healthcare. Changes in engineering education happen in order to make students industry ready as per recent trends and technologies [17]. These new technologies that form main pillars of industry 4.0 are [10, 18, 19]: Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cyber security, The Cloud, Additive Manufacturing, Augmented Reality. Some of the key issues for engineering education are how to cover all these new technologies in different courses (and curricula), how to accomplish that task at affordable prices (especially important for developing countries) and how to provide problem-based learning for students, with fully understanding what engineering in Industry 4.0 really is. Different engineering courses and curriculums used different approaches in order to improve teaching and learning outcomes. Among different approaches some of them used low cost hardware platforms and prototyping boards such as Arduino, Raspberry Pi, BeagleBone and NodeMcu [20, 21]. These boards and solutions based on them have been used in number of undergraduate engineering courses such as Automatic Control and Robotics [22], programming and engineering [23]. The goal of this paper is to present affordable solution that could be used in engineering education in order to solve previously mentioned problems. The goal of this paper is to present application (possible educational setups and tasks) of affordable microprocessor boards and sensors that could be used in engineering education to teach some of Industry 4.0 concepts. We will present solution based on

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NodeMcu in order to provide platform for students to work with sensors, programming, cloud systems and other key technologies vital for industry 4.0. Also, we will present inclusion of affordable microprocessor boards in development of web-distributed measurement and data acquisition system in laboratory classes with simple or semi-industrial plants, as well as, educational goals and students' satisfaction with these systems.

2. Literature Review

The usage of low-cost boards is not a new concept. There are number of benefits and challenges of using modern prototyping microprocessor boards – Arduino, Raspberry Pi, BeagleBone Black and NodeMCU used in a number of our courses for student projects of many different levels [20]. Some users have been selecting Arduino, because of its open-source nature, which is supported by a vast user community who share their ideas, projects and solutions [23]. Arduino could be used on its own, or as platform for development of virtual and remotely controlled laboratories. The results of some research [24] reflects that LabView-Arduino is a viable and reliable tool for the implementation of virtual plants for laboratory practices offering the possibility to implement a large number of virtual applications. Fernández-Pacheco et al. [25], presented Arduino Remote Laboratory with Raspberry Pi with the aim to give a support to on-line IoT learning experimentation environments, which are very important to provide quality on-line education programs on IoT. The Arduino tool could be also used as digital controller for the undergraduate control system course with two examples (PID control and the other is fuzzy control) [26]. Remote web-based control laboratory for mobile devices based on EJsS, Raspberry Pi and Node.js for Systems Engineering and Automated Control is also one of the reported solutions [27] or with other open source solutions [28]. It is clear that the new generation of less costly hardware and data acquisition equipment give opportunity for development of complex web laboratories and very useful solutions for engineering education too [29]. These hardware platforms also could be used as low-cost wearable human-computer interface for STEM education [30], for teaching embedded operating systems [31] as well as for many other educational purposes.

These modern prototyping microprocessor boards – Arduino, Raspberry Pi, BeagleBone Black and NodeMCU have very interesting and important function in prototyping, as well as, in education, but it also has been reported that these platforms could be used in industrial / business environment [32]. It is clear that these boards cannot match industrial boards, computers and PLC in many different aspects, but they could bridge or solve some issues (especially in situation with low financial resources). Number of practical implementation of these systems have been reported globally for: industrial process monitoring [33]; assessment of foam quality in sparkling wines [34]; Smart Monitoring of a Water Quality [35]; design of portable 3-axis filament winding machine with inexpensive control system [36]; control on the metabolite content [37]; water quality and quick alert of flooding [38]; pollution monitoring [39]; indoor air quality monitoring and control system [40–44]; industrial automation [45], IoT application for industry 4.0 [46]; smart AGV System for Manufacturing Shop floor [47]; or building industrial CPS [48]. In addition, mentioned microprocessor boards could be used for some practical purposes, so the education and training incorporation of this hardware could be useful in many different directions.

Two things could be concluded: the first one that modern prototyping microprocessor boards – Arduino, Raspberry Pi, BeagleBone Black and NodeMCU already present important educational platform for number of undergraduate engineering courses, and the second, even some industrial solutions could be based on this platforms. On the other hand, it is hard to predict future developments, but it is reasonable to expect that some of these platforms will emerge in industrial form. This is a reason why we have introduced these microprocessor boards in educational and training process, even more we wanted to extend the implementation of these boards and accompanied acquisition system, by employing cloud systems and providing different forms of data presentation, which could provide the framework for global educational web laboratories.

3. Prototyping Microprocessor Boards in Engineering Education – an Example

In engineering education and in the set of courses that have been performed at the Faculty of Engineering, University of Kragujevac, students could select one of defined problems such as: Monitoring of indoor environment; Monitoring of water quality; Greenhouse Monitoring System; access control based on RFID; Smoke/Gas Leakage Indicator or Alarm; Industrial safety monitoring system, etc. All of them have same educational goals enabling students to understand and use: sensors and transducers, laboratory classes with semi – industrial plants, application and architecture of microprocessor – based measurement and data acquisition systems, and web-distributed measurement and data acquisition system. In the same time, students will also get familiar with programming, data bases and cloud systems. In this paper, one of the examples will be presented: System for monitoring of environmental factors.

3.1 System for Monitoring of Environmental Factors

The example that will be covered is monitoring of the indoor environment, considering that as an important issue since people spend most of their days in the indoor environment. Thus, indoor air quality is recognized as an important factor to be controlled, for the occupants' health and comfort [43]. There are numbers of these systems, starting from simple one up to very complex system [40–44]. In this paper we will present one of these systems that are developed and used for educational purposes.

The general idea, for the students, is to present system that could have different level of usage: to have portable system that could be carried on, to measure parameters on the spot (even as wearable sensors), to provide data acquisition on local computer, or web server and to present more complex system (storage of data on the cloud, definition of public channels, joint solutions and presentation on different platforms).

System is based on NodeMcu over Arduino Uno, since NodeMCU has the Wi-Fi feature, and a slightly greater capacity, at the same price. NodeMcu communicates with two sensors fc-22, dht-11, breadboard, relay module and LCD display. There are following different tasks to be accomplished (Fig. 1):

1. Provide measurement of the temperature expressed in Celsius and Kelvin, as well as in Fahrenheits', air humidity, condensation temperature, accelerated condensation, air pollution covering several types of harmful gases on the spot and present values on LCD monitor.
2. Provide data acquisition to computer and enable data analysis using Excel or other software for data analysis and presentation.
3. Present data on the web, using regular web server infrastructure.
4. Store data on the cloud using ThingSpeak, provide data analysis, present and distribute data on mobile platforms by applying Virtuino.
5. Provide API for development of more complex application, which will include sensors network, as well as, legacy systems.

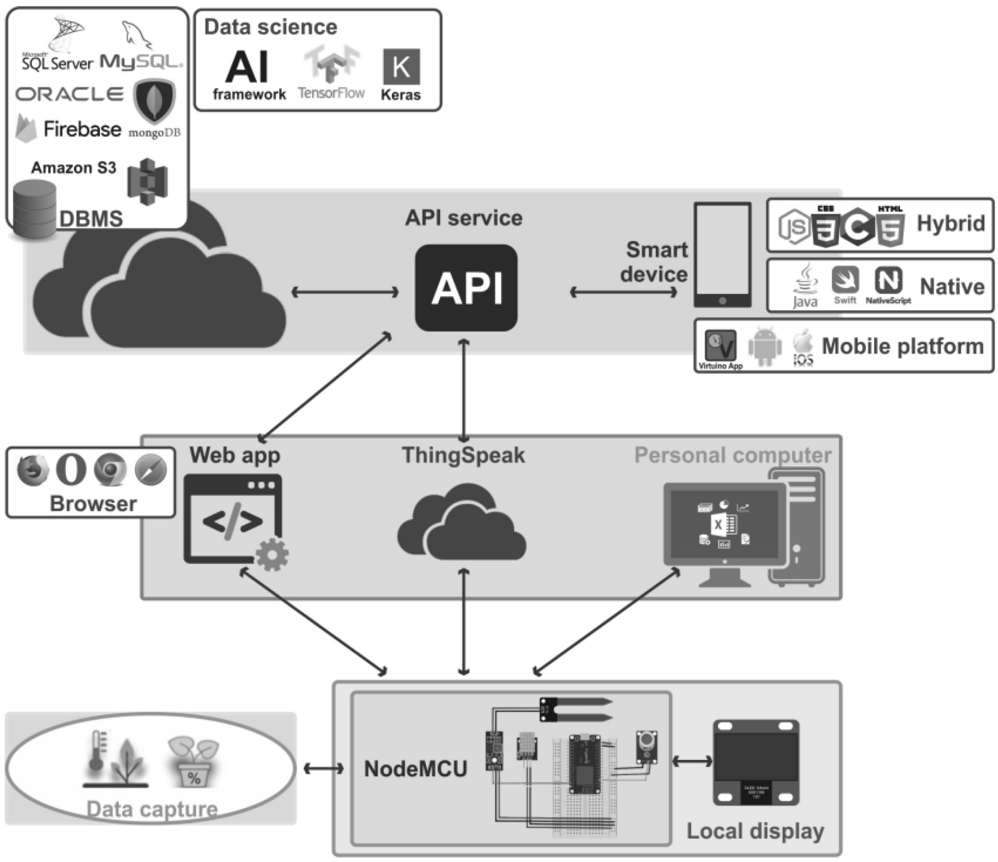


Fig. 1. Architecture of the system with different solutions for integration and data presentation.

NodeMcu enables the communication with sensors and it is used to present some capabilities provided by ThingSpeak platform. In this paper, the NodeMcu V3 platform model, as well as, sensors fc-22 and dht-11, breadboard, and relay module were used. This system displays data on a web site in both real-time and packet-arithmetic environments, minimum and maximum values, collected by sensors. Data can be accessed at any time and from anywhere. Used sensors measures temperature expressed in Celsius and Kelvin, as well as in Fahrenheits, air humidity, condensation temperature, accelerated condensation, air pollution covering several types of harmful gases. They also provide the ability to store data in a database that is located on the Internet, as well as, in a local database, which provides the ability to control the platform itself over the Internet, with a computer or mobile phone. The paper, itself, demonstrates four different application models.

3.2 Hardware Architecture of the System

In order to fulfill selected task, the following components were used (Fig. 2):

- **NodeMcu** – an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.
- **Sensor fc-22** for detection of harmful gases in the air is one of the many sensors used in industry for monitoring of air pollution. It is sensitive on steam, gas, ammoniac, sulfur, gasoline, smoke, alcohol and other.
- **Sensor DHT11** for temperature and humidity is used for gathering data about listed factors.
- **Relay module** – A relay is an electrically operated device. (Digital module; 10A(NO) 5A(NC), Maximum total voltage: 150VAC/24VDC, digital interface, Control signal TTL level;)
- **Breadboard** – construction base for prototyping of electronics.
- **LCD** display – flat-panel display.

The complete set up consists of NodeMcu board, breadboard used as construction base for prototyping and two selected sensors for measurement of temperature, humidity and air pollution (fc-22 and DHT11 sensors), module for external power supply and LCD module for direct presentation of measured data.

Arduino Create is an integrated online platform used to write code, access content, configure boards, and share projects. The usage of this on-line platform is possible through Arduino web editor, Project Hub, Device Manager or Arduino IoT Cloud. In addition, it is necessary to write 3 parts of the program, while using Arduino Create (we can also use it for NodeMcu):

1. The top part with declaration of variables (to include libraries, set MAC and IP addresses, sensor Objects),
2. setup – where initial conditions for program are predefined (open port and start communication, set IP address to access results),
3. loop – part that runs over and over again, while performing bidding (set listener, presentation of data, if condition has been used, to set maximal pollution value at 350 digits).

During this part of preparation, connection between board and programing computer has been established.

3.3 Software Infrastructure of the System

3.3.1 Presentation of Data on Web

In this model, a goal was to read data from sensors and to present it on a computer or phone in a real time. The first step is connection of NodeMcu platform on the WIFI, then to set server and define ssid

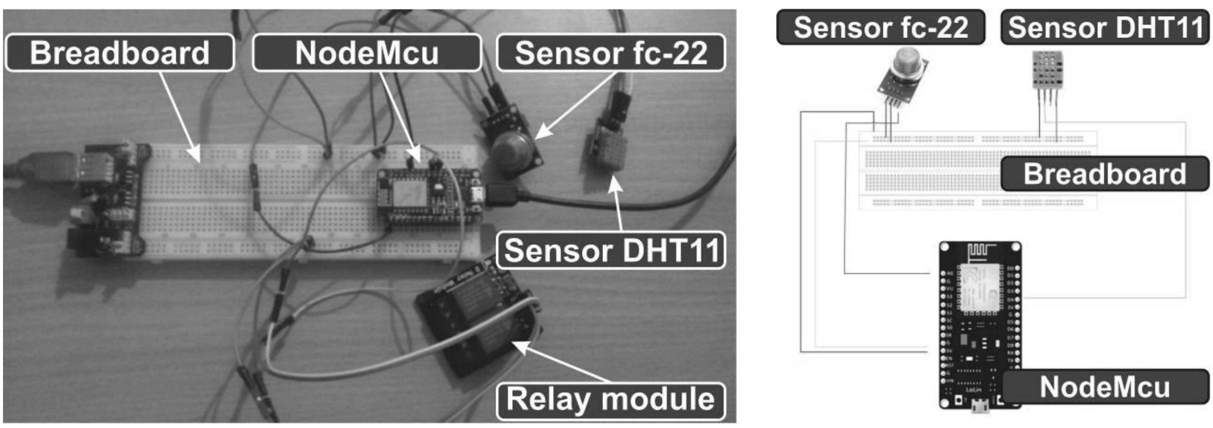
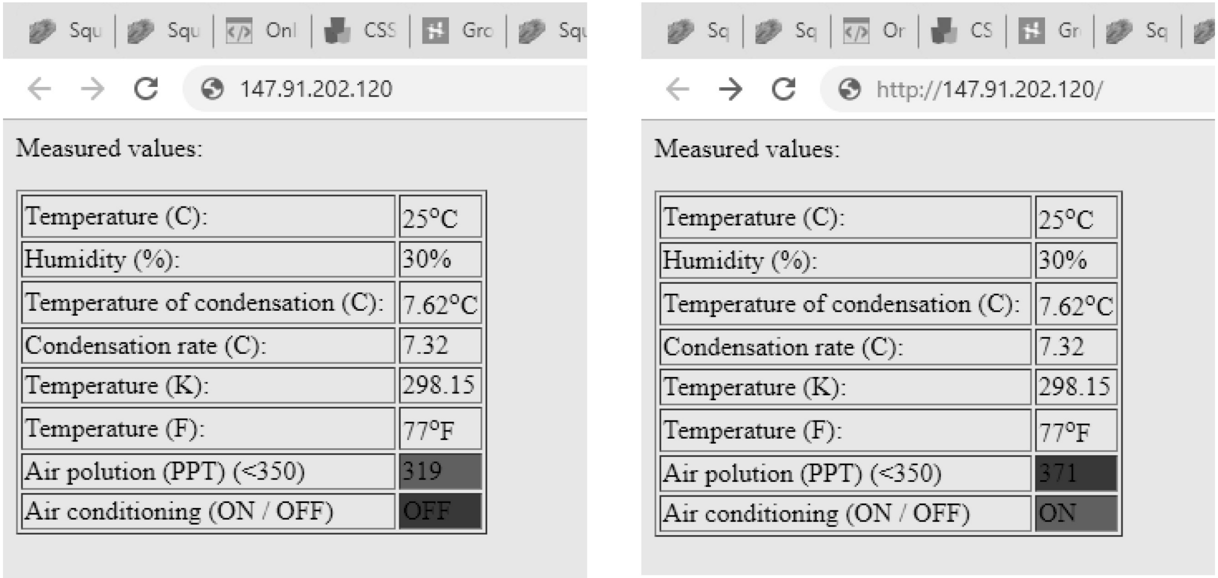


Fig. 2. Set-up for measurement: NodeMcu with fc-22 and DHT11 sensors.



a) Air pollution is below the defined limit and air conditioning is OFF

b) Air pollution is above the defined limit and air conditioning is ON

Fig. 3. Presentation of data on the web.

and password for NodeMcu platform, define pin for connection, sensors and type of sensors. It is necessary to open a communication port, since library has been used, it was not necessary to set IP, subnet and gateway, but just applicable ssid and password. Function void setup is executed, as long as the client is connected with a server. Two functions have to be defined: void setup and void loop (this functions are executed, as long as the client has connection with server). Variable val, representing air pollution, has also been appointed. If the value is greater than 350, the client will be informed about air pollution.

Fig. 3 presents data from sensors as well as notice (about increased pollution). In Fig.4a. the air pollution is below the defined limit. In that case, users are informed that air conditioning is OFF. In Fig.4b, pollution is above the defined value. In that case, air conditioning (small ventilator) is turned ON.

3.3.2 Desk top Visualization using Excel PLX-DAQ

In specific situations (working in remote locations), users do not have access to the Internet, so this is a local solution to provide data acquisition on desktop, laptop computer or even Raspberry PI, and make simple analysis using Excel or similar platforms (SPSS).

This solution is based on PLX-DAQ. PLX-DAQ is a Parallax microcontroller data acquisition add-on tool for Microsoft Excel enabling any of our microcontrollers to be connected to any sensor and the serial port of a PC in order to send data directly into Excel (using USB connection). This is both an advantage and a disadvantage, since this solution needs computer support, but also enables a large amount of storage space. The first step is to install and start add on PLX-DAQ, second is to set Port and Baud (to use same port we used to program NodeMcu platform and provide data transfer). After establishment of a connection, the client can select different types of graphics for data presentation (Fig. 4). It is also necessary to use libraries for sensors FC-22 and DHT11, and define necessary pins, as well as the type of sensors.

In the function ***void setup,*** it necessary to set Baud on the port 9600 and use it in PLX-DAQ for connection. In the function void loop, we read data from sensors with time. NodeMcu read data every second and write in PLX-DAQ (where data can be stored, processed and used). Fig. 4 presents' data form sensors temperature, humidity and pollution.

3.3.3 Presentation using ThingSpeak as Proxy Server

ThingSpeak is an IoT analytics platform service that allows the user to aggregate, visualize, and analyze live data streams in the cloud. Data could be accessed by a computer or mobile phone with an Android system. The first step is to register and create a channel, with channel ID and API Key (Write API Key, Read API Key) defined. In channel settings, it is necessary to set: name, description, field (ThingSpeak channel can have up to 8 fields), Metadata, Link to External Site, Show Channel Location Latitude, Longitude, Elevation, Video URL and Link to GitHub). Also, it is possible to set channel as private or public.

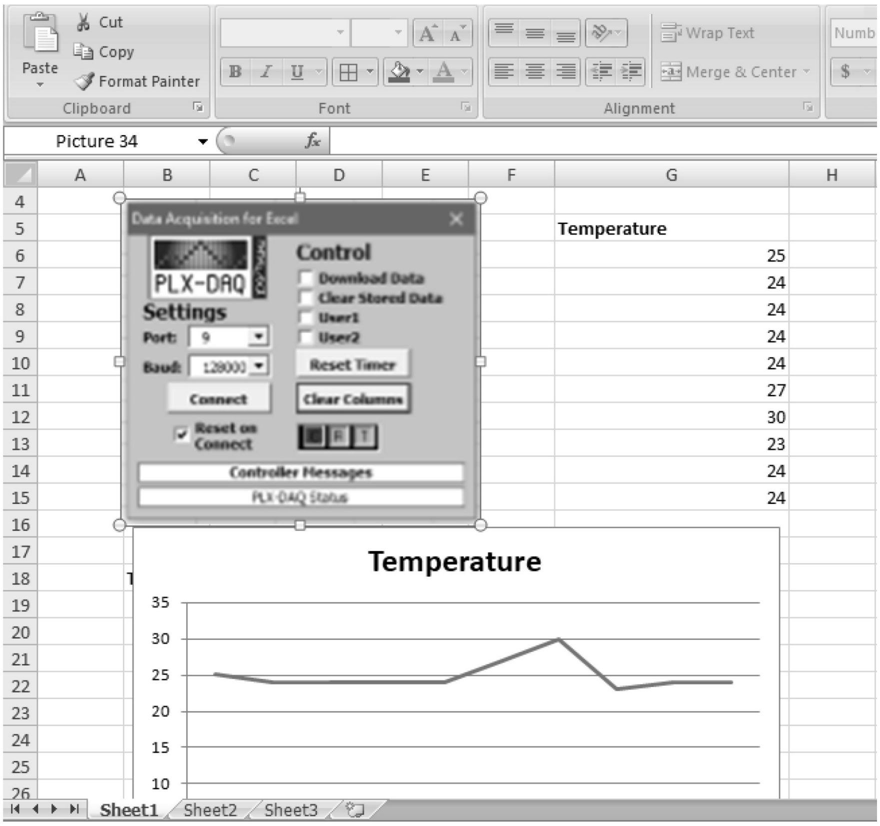


Fig. 4. Data acquisition and presentation from sensors using PLX-DAQ.

It is necessary to define ssid and password for connection by using Wi-Fi, so it is necessary to set clients and number of channels mySensorsChannel-Number, as well as, myWriteApiKey_sensors, pin for DHT11 and type of sensors. In this way, function void loop may read data from sensors, while using void setup function values, ThingSpeak listen client, and repeating the procedure for each second.

Data is stored on to the cloud (Fig. 5) where they can be aggregated, visualized, and analyzed within

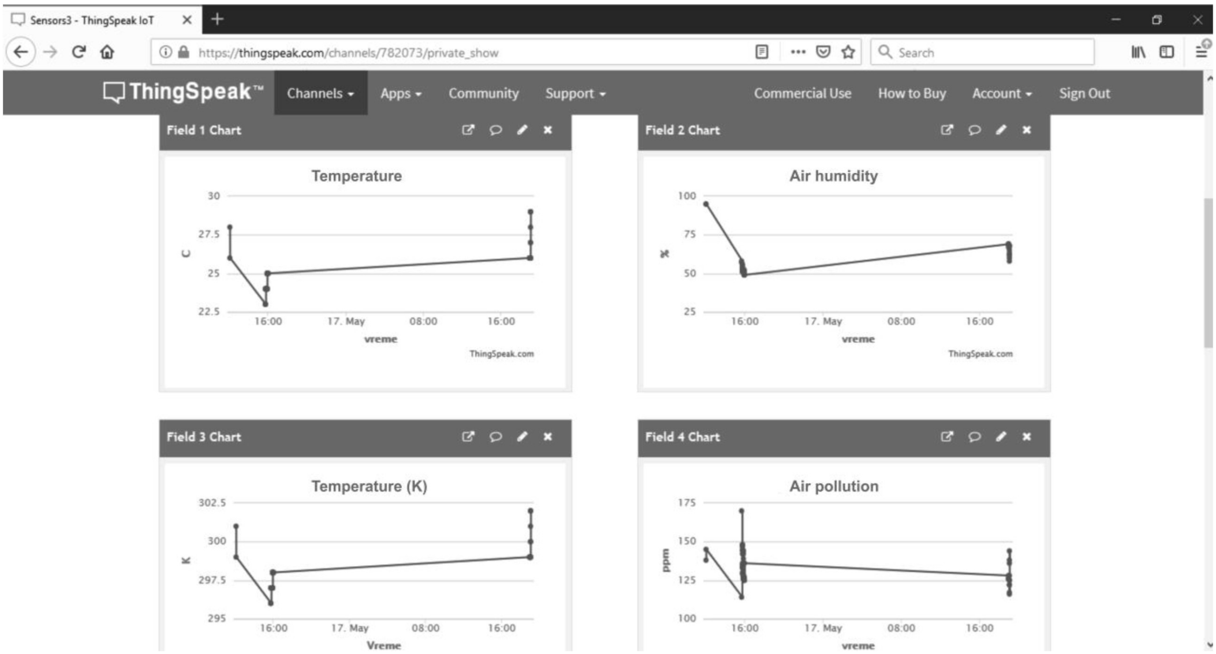


Fig. 5. Presentation of Charts with data: Temperature, humidity and pollution.

live data streams from out NodeMcu platform (with two different sensors).

3.3.4 Presentation using Virtuino

Virtuino is an HMI platform for IoT servers, Arduino ESP and similar boards and enable virtual screens on your mobile phone or tablet to control every automation system via Bluetooth, Wi-Fi or Web. First of all, it is necessary to install Virtuino on the mobile system in order to access, using Internet connection to ThingSepak and get data for visualization. Number of reports suggested usability of smart phones in education, so students need to learn about smartphone devices usage for learning, as well as, for programming solutions for smart devices [49]. The second step is to create a server for data connection by including Channel ID and ReadKey for specific ThingSpeak Channel. Also, it is possible to browse the history by date and time by searching for the needed data from the data base.

Using Virtuino it is possible to control specific inputs or outputs on NodeMcu. Firstly, it is necessary to select pin where specific sensor is attached, then it is necessary to add control button and select pin with relay module, which enables the option to turn off or turn on device connected to relay module.

4. Educational Tasks and Results

4.1 Educational Task

The main idea is to provide educational set up and educational task that could be used as practical exercise in a number of undergraduate engineering courses such as: Sensors and transducers, Microprocessor Electronics, Control Systems Technology, Microprocessor based measurement and data acquisition systems, Technical Equipment for Control Systems, Web Programming, Web-based Measurement and Data Acquisition Systems. Initial assignments are given to the students, including: monitoring of indoor environment; monitoring of water quality; smart agriculture; access control based on RFID . . . (Table 1) and then students need to select components and follow the suggested software tools to solve specific problem and join their solution to the network (all students are presenting their solutions in the network that cover different sensors, sensor networks and presentation channels). During the courses, after theoretical background, the system for monitoring of indoor environment has been presented in details, and then students selected their own problems.

The presented setup could be used in engineering education for the following educational goals and educational outcomes:

- Acquiring of basic knowledge in the field of sensors and transducers, physical properties of sensors. Dependency of change of physical parameters on the quantity being measured, as well as ways to connect sensors in electric or electronic circuit and sensor signal conditioning. Ability to choose the appropriate sensor and transducer for different purposes.
- Enabling students to make models, modular designs, simulate and implement hardware functional units and microcomputer systems based on the microprocessors and microcontrollers.
- Basic theoretical and practical knowledge which

Table 1. Steps in educational tasks

Steps	Description	Presented case
Selection of the problem	Students could select one of defined problems (Monitoring of indoor environment; Monitoring of water quality; Greenhouse Monitoring System; access control based on RFID; Smoke/Gas Leakage Indicator or Alarm; Industrial safety monitoring system...)	monitoring of indoor environment (Temperature, humidity, air pollution)
Selection of hardware components	Microprocessor board, sensors...	NodeMCU
Connecting sensors	Connecting selected sensors	fc-22 and DHT11 sensors
Programing MPCU	Using on line editor or selected editor	Arduino Editor
Connection of LCD module	Presentation of measured data on LCD screen	LCD module
Connection to local computer or lap top	Data acquisition and presentation using PLX-DAQ and Excel	PLX-DAQ and Excel
Web presentation of data	Presentation of data in web browser	Web server, Chrome
Storage of data on cloud	Storage and presentation of data on cloud Arduino, ThingSpeak (Freeboard), setting channel, API	ThingSpeak
Presentation of data on mobile devices	Presentation of data using Varduino, Reject, Angular	Varduino
Definition of closed loop	The relay switch unit on or off	Relay module
Participation in network	Integration of different channels into network	ThingSpeak

enables understanding of laboratory classes with semi- industrial plants (temperature regulations, level and flow, Ph value, DC motor, robotic hand, digital signal processing, SCADA), as well as, understanding of processes encountered with real life industrial plants.

- Understanding application and architecture of microprocessor-based measurement and data acquisition systems; the ability to work in interdisciplinary teams, in order to understand and solve problems related to the application of microprocessor-based measurement and data acquisition systems.
- Students would acquire the basic principles of communication networks. It is intended to clarify the fundamental problems at network layers.
- The structure of web-distributed measurement and data acquisition system. Types of data acquisition module in distributed measurement and acquisition systems in different applications (industry, environmental protection, energy systems, and appliances): smart sensors, RFID tagged objects, dedicated embedded measurement and data acquisition systems, and computer measurement and data acquisition systems. Expansion of data acquisition modules with integrated web servers and web applications. The role and implementation of servers in distributed measurement and data acquisition systems. Client applications in distributed measurement and data acquisition systems. Stand-alone client applications and web client applications. Client devices: computers, general-purpose embedded systems dedicated to portable devices for general use. Cloud service integration in web-distributed measurement acquisition systems. Programming and deployment data acquisition modules.

Students in some of the mentioned courses, in the first step, need to select problem to be solved (such as monitoring of indoor environment). Then students need to prepare report that will cover (Table 1): selection and description of appropriate sensors for specific purpose; description of selected board and set up of the system; program for selected board; report in Excel; report on web server; channel on ThingSpeak, API; and report of role of specific measurement in the team work. In previous section task: monitoring of indoor environment was presented.

4.2 Educational Results

Results were evaluated taking into account the views of students, concluding that the proposed experiments have been attractive to them, and they have acquired the knowledge about hardware configuration and programming that was intended (Table 2). The NodeMCU platform can be started and learned quickly. Thus, students are focused on the problems of the experiments, such as the development and programming.

The research has been performed on the total number of 76 students from study program computers and software engineering. The main conclusion is that the students shown interest to solve real life problem and to use knowledge and skills from different courses (sensors, microprocessors, networks and web-distributed measurement and data acquisition system). According to Table 1 students find concepts of storage data on the cloud and mobile applications development as the most interesting one, on the other side air pollution e “classical” approaches were less interesting (presentation of data on LCD monitor). Students (Table 3) also find that presented approach enables them to acquire knowledge and skills as well as they highly rated complete concept. Overall, the students like the low cost of these devices and the ease of use that allows them to create significant projects. Also, some other researchers suggest the same conclusion [20].

5. Discussion

The new knowledge, as well as, multidisciplinary approaches and integration of different knowledge and skills for students, and trainees are required. The important shift needs to happen to educational institutions, study programs and courses as well. In the core, the shift will be toward real-life problems from society, based on ICT and other core technologies of Industry 4.0: Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cyber security, The Cloud, Additive Manufacturing, Augmented Reality.

Table 2. Students evaluation of specific steps (76 students from study program computers and software engineering)

Steps	**Grade 1–5 (highest)**
Selection of the problem	4.1
Selection of hardware components	3.7
Connecting sensors	3.5
Programing MPCU	4.0
Connection of LCD module	3.1
Connection to local computer or lap top	3.3
Web presentation of data	4.2
Storage of data on the cloud	4.7
Presentation of data on mobile devices	4.8
Definition of closed loop	4.1
Participation in sensors network	4.6

Table 3. Students satisfaction and opinion (76 students from study program computers and software engineering)

No	Question	Grade 1–5 (highest)
1	Do you believe that this kind of problem solving contributes to engineering education?	4.1
2	Does this kind of work contribute to your knowledge of modern technologies (industry 4.0, web-distributed measurement and data acquisition system?) ?	3.9
3	Do you have better understanding of understanding of laboratory classes with semi- industrial plants	4.6
4	Do you like to work with low cost prototyping microprocessor boards?	4.2
5	Do you find programing of these boards easy and user friendly?	4.1
6	Do you find useful providing cloud support?	4.4
7	Do you believe that this approach is useful in engineering education?	4.5
8	Is the example useful for better understanding of the structure of web-distributed measurement and data acquisition system?	4.7
9	Do you believe that this project is good for your creativity?	4.9
10	Please rate the suggested tasks and complete procedure	4.8

On the other hand, prices of different prototyping microprocessor boards are decreasing, as well as, prices of different sensors that could be used in educational process. Also, right now there is wide variety of these solutions which have Wi-Fi connections, as well as, even industrial implementation. In this paper authors suggested the usage of this components in engineering education. We presented educational set ups and used them at University of Kragujevac, where students apply prototyping microprocessor boards and sensors for solution of real-life problems. Also, we presented educational task and example that is presented to students. The example is the indoor air monitoring system. This system displays data on a web site in both real-time and packet-arithmetic environments, minimum and maximum values, collected by sensors. Data can be accessed at any time and from anywhere. Used sensors measure temperature expressed in Celsius and Kelvin, as well as, in Fahrenheits, air humidity, condensation temperature, accelerated condensation, air pollution, covering several types of harmful gases. It also provides the ability to store data in a database that is located on the Internet, as well as, in a local database, and it provides the ability to control the platform itself over the Internet, with a computer or mobile phone. The paper itself demonstrates four different application models (local, on web server, on the cloud and mobile devices). After the presentation of an example, students select their own problem to solve, and they prepare report base on same template, also they need to interconnect their solution into network with other students (Table 1). The presented solutions is (starting from task from Table 1) expandable, so that the low cost sensors network can be created.

6. Conclusion

Based on the presented facts, it may be concluded that education based on problem solving approach with real life problems employing different Industry 4.0 core technologies provide both increased students satisfaction, better educational results and functional knowledge in different fields (sensors, microprocessors, networks and web-distributed measurement and data acquisition system).

In addition, according to different educational goals, fields, experience, and measured satisfaction of the students, the conclusion is that this affordable component could be very useful in engineering education, since students' responded quite positive (Tables 2 and 3).

It could be concluded that in modern engineering education multidisciplinary approach is very important, especially when having in mind emerging concepts such as Industry 4.0. We presented selected set ups, educational tasks and goals and students feedback. In this paper application of low cost components, microprocessor boards and sensors we presented from educational standpoint, as well as practices/techniques used to include these devices in number of engineering courses. Low cost components could be used to depict the major concepts in teaching fundamentals of Industry 4.0. Additional benefit is that some of these components also have industrial versions on one side, and on the other side presented components are affordable for educational institutions all over the World, even in developing countries. Overall, the students, according to our research and questionnaire, students like the low cost of these devices and the ease of use that allows them to create different projects and set ups, demonstrating their knowledge and skills in various fields (Selection of hardware components, programming MPCU, sensors, web programming, cloud computing. programming of mobile devices . . .). Although these low cost systems prove to be an excellent educational tool, and could be useful for many real applications, it is necessary for students to have contact with industrial and commercial equipment.

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