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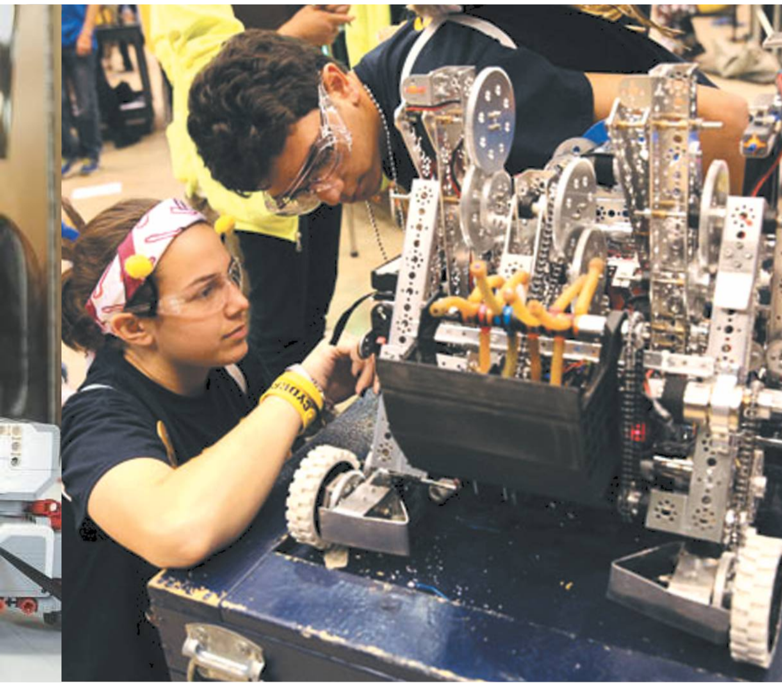


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# Project-based Laboratory Assignments to Support Digital Transformation of Education in Turkmenistan

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**Abstract:** On 30th of November, 2018, by the Decree of the Esteemed President of Turkmenistan Gurbanguly Berdimuhammedov, there was accepted a Conception of developing digital economy in Turkmenistan in between 2019-2025. Moreover, on 15th of September, 2017, the Conception of developing digital education in Turkmenistan was approved as well. That is why, new, innovative methodologies and digital solutions are continuously being introduced to the educational system of Turkmenistan. Teaching and training undergraduate students, studying in the field of automation and control engineering, is a tough issue. Because, nowadays, for automation engineer, knowing physics, mathematics, theory of automation and electronics is not enough, moreover, they should also know basics of smart systems, if necessary, programming a microcontroller and methods of using necessary sensors when designing smart systems. In this regards, this paper provides useful information about the steps and key points of integrating digital solutions and microcontroller-based educational methodologies into the undergraduate educational system of Turkmenistan. Moreover, the effect of the proposed method of teaching and appropriateness of the laboratory assignments were also analysed at the end of the course. As a microcontroller board, "Ardunio UNO" was selected as it is easy-to-learn.

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**Keywords:** smart systems, engineering courses, "Arduino UNO" board, methodology of achieving course objectives, Bloom's taxonomy

## 1. Introduction and literature review

There are several methods or types of undergraduate teaching in terms of the way that students gain intended knowledge, skills or abilities. In general, these techniques can be classified as instructor-centred, student-centred, content focused and interactive methods. Abanador (2014) points out that students, who are studying engineering courses, prefer all the methods of teaching such as teacher-centred, learner-centred and content-focused methods in order to better understand the content of the lecture. Moreover, because embedded systems are widely used in automation, industry and computerized systems, teaching embedded systems could also include various methods such as hardware-oriented, software-oriented, or hardware-software integration (Ibrahim et al., 2015). Therefore, in this paper, learner-centred method was chosen to conduct experiments and reach intended goals.

As it was pointed out in the report, "due to a greater emphasis on science, technology, engineering, and mathematics (STEM) education to prepare students for future economic needs and the challenges of the next generation, the maker movement advocated by a number of governments worldwide is a vital learning trend of innovating educational environments" (Horizon Report, 2016). Because maker education environments make it possible for learners or students with similar interests and diverse experiences to employ various digital tools to construct, build or make a project by realizing creative ideas of each other (Lee, 2015). That is why, the authors proposed that maker education or project-based learning could help learners to develop skills such as problem-solving and creative thinking, and be educated in different directions of engineering, therefore, they believe that maker education increases or fosters curiosity, tinkering, and iterative learning, which in turn leads to better thinking abilities through better questioning (Kurti et al., 2014). In teaching students of engineering fields, project-based learning may be one of the effective ways (Dym et al., 2005), it could be better experience to direct the students to build goal-oriented projects using a microcontroller, which will result in capacity building and creative thinking skills. In this context, Benitti (2012) offered that future research should take in different educational products of robotics such as Arduino-based educational products for teaching and learning strategies. As Lee (2015) states in his article, variety of available microcontrollers which can be used in education processes, is always changing, but well-known choices nowadays consist of Rasperry Pi, Arduino, BeagleBone, Launchpad and Quark, each of which has different models as well. Among these options, using Arduino platform in the educational process of embedded engineering was proven to be one of the effective platforms (Mohammed, 2017). On the official website of developers, Arduino is defined as "an open-source electronics platform based on easy-to-use hardware and software" (https://www.arduino.cc/en/guide/introduction). In general, a microcontroller can be defined as a tiny, programmable computer on a microchip that is able to process input signals from transducers or sensors of physical quantities, switches, internet data, and control various output devices or loads including servo and step motors, light emitting diodes, lamps, and speakers, and can store information in a memory card or web portal (Lee, 2015). Moreover, Mohammed (2017) states that "Arduino became more and more popular among academics, the number of publications involving the Arduino platform has considerably increased over the years". This indicates the necessity of teaching undergraduates the basics of designing smart or automated systems in a way that they could effectively implement their knowledge in the application.

It is indeed a challenging issue to implement advanced technologies in the higher education and the key questions in doing so are "where to start?" and "how to test the technology-based skills of students" (Kriti, 2018). Because the pace of learning of any subject is not the same for each student and student diversity is always an issue for instructors, Student Experience Transitions Model (Morgan, 2013) may be implemented in teaching engineering as well.

As with many other attempts to develop innovative educational methods, Son and Sohn (2014) have also worked out an educational method in which they integrated science, art and information technology in teaching programming courses. Moreover, the authors developed an Arduino-based educational program to improve the ability of students to design and implement a creative solutions to the real world problems and to test their skills (Seong et al., 2017). As they point out in the article, "students were interested in and felt a sense of accomplishment in participating in the Arduino-based education program" (Seong et al., 2017). Moreover, in order to promote better Science Technology Engineering and Math (STEM) education, authors developed hands-on laboratory assignments based on Arduino microcontroller (Hoffer, 2012).

Therefore, in this paper, methodology of implementing Arduino-based learning environment in teaching undergraduates of engineering fields is being discussed and possible directions, solutions or proposals are being offered. This will be useful tool or method for the instructors and lecturers of higher educational institutions in Turkmenistan in achieving global objectives of any course such as decision making, brainstorming, project development and rational reasoning, whereas learners will also be satisfied with the technique being used.

## 2. Content of a course curriculum and its relevancy of Arduino-based learning

In order to inject new methods to the education, matching the educational method with an appropriate course is one of the most important tasks. Therefore, after brainstorming with lecturers, as a course in which Arduino-based learning environment is proposed to be implemented, "Control instrumentation and measuring devices" was selected. This course is taught in undergraduate disciplines such as automation, robotics, and control engineering. The duration of the course is 2 academic semesters, and the division of hours within the course, including lectures, problem-solving and experiments, is being approved by Deputy Chairman of Cabinet of Ministers of Turkmenistan, while the curriculum of the course is regularly being confirmed by a rector or vice rector of the higher educational institutions each academic year. The “Control instrumentation and measuring devices” course consists of 34 hours of lecture, 18 hours of problem-solving and 34 hours of laboratory works. The main goal of the course is to teach undergraduate students about control systems, types and working principles of sensors and measuring devices, methods or ways of using them, instrumentation of automated systems, basics of smart systems and digital solutions in control engineering. As the main directions of technical higher educational institutions such as State Energy Institute of Turkmenistan are power engineering, energy supply, automation and relay protection, the selected laboratory assignments, as in a Table 1, are closely related to electrical energy issues such as energy saving, energy monitoring, energy metering, effective consumption of electrical energy and implementation of smart solutions in this sector.

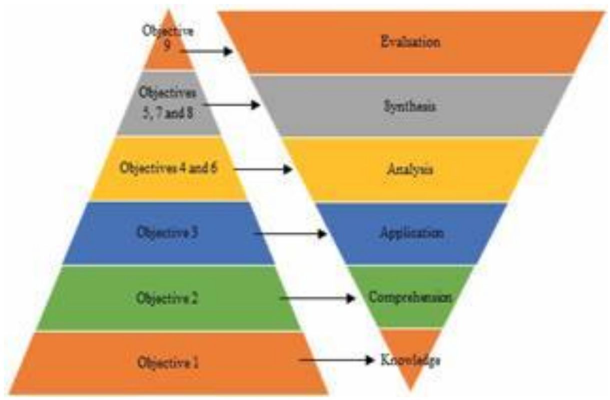


**Fig. 1: Objectives of the laboratory assignments in parallel with Bloom's taxonomy**

In the lecture section of the course, mainly theoretical part of the subject is delivered to students, while in problem-solving part they solve questions, problems or tasks related to the topics taught in lecture hours. Next comes the laboratory part in which students are fostered to carry out specific experiments such as designing smart or automated mini-systems, measuring devices and thereby understand the working principles of sensors and measuring instruments. Therefore, during realization process of proposed laboratory assignments, implementing the components of “Reorientation and induction” stage of SEPT model (Kriti, 2018) was also taken into account. In fact, by introducing these assignments to the undergraduate course curriculum, demands of modern job market was also considered and employability of students was fostered.

Usually, for one experiment 4 hours or 2 couple hours are given to complete the tasks, while one couple hour is planning part and other one is designing and implementing part. Therefore, minimum 9 laboratory assignments were required to complete all the experimental hours. As shown in the Table 1, first two hours were spent to get familiarized with the instruments, tools and platforms of microcontroller-based experiments, while remaining 32 hours were covered with 8 laboratory works, one for each 4 hours. The assignments were ordered in a way that the concept in each experiment is getting deeper in terms of its objectives as per Bloom`s taxonomy (Anderson and Krathwohl, 2001) which is shown in Fig. 1. In other words, the taxonomy includes the cognitive levels such as Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation, and the key words or verbs that describe each level gets more sophisticated as the level increases.

As Bloom's taxonomy consists of mainly six cognitive levels, each objective was planned in accordance with the taxonomy. In fact, intended objectives gradually require more cognitive skills. Moreover, topics of laboratory assignments were selected among the most focused priorities of both State educational policy and demands of modern education such as digital transformation, smart systems and interactive learning. In this way, laboratory assignments were carried out in accordance with the requirements of pedagogy and priorities of the State educational policy.

**Table 1 : Proposed laboratory assignments for the “Control instrumentation & measuring devices”course**

| № | Name of the assignment | Required tools | Objective of the assignment in regards with the Bloom’s taxonomy | Intended laboratory hours |
|---|---|---|---|---|
| 1. | Elements of microcontroller-based automated systems | Arduino UNO board, sensors of physical quantities (motion sensor, voice sensor, temperature sensor, moisture and humidity | To describe basics and logics of smart systems, to identify sensors and actuators | 2 hours |

| | | | | |
|---|---|---|---|---|
| | | humidity sensor, ultrasonic sensor and etc.), relay modules, several types of loads (motor, lamp, buzzer, LED) to be controlled | | |
| 2. | Smart systems based on light intensity | Arduino UNO board, photo-resistor, relay, lamp, potentiometer | To understand working principles of smart systems and to explain logics of designing them | 4 hours |
| 3. | Smart systems of saving electrical energy and using electricity effectively | Arduino UNO board, motion sensor, thermo-resistor, relay, bipolar junction transistor, lamp, fan, motor | To implement digital solutions for energy saving and to produce smart systems | 4 hours |
| 4. | Smart energy metering and distant energy monitoring device | Arduino UNO board, ACS712 current sensor, ESP8266 WiFi module, SIM900A GSM/GPRS module, SIM card, 16x2 liquid crystal display (LCD) | To compare different kinds of energy meters and to implement IoT (Internet of Things) solutions in energy metering | 4 hours |
| 5. | Smart measuring device of water consumption | Arduino UNO board, YF-S201 Hall effect water flow sensor, SIM900A GSM/GPRS module, solenoid valve, relay | To construct water management system and to examine connection diagrams | 4 hours |
| 6. | Smart ventilation system for greenhouses | Arduino UNO board, DHT11 temperature and humidity sensors, relay, fan | To compare different values of the same physical quantity, to analyze smart systems | 4 hours |
| 7. | Smart alarm system for gas leakages | Arduino UNO board, MQ5 type gas sensor, relay, active buzzer, SIM900A GSM/GPRS module, solenoid valve, LCD | To design smart systems and to create digital solutions to daily-life issues | 4 hours |
| 8. | Smart overload protection system for home appliances | Arduino UNO board, ACS712 current sensor, relay protection, potentiometer | To protect electrical devices from over currents and to propose appropriate solutions | 4 hours |
| 9. | Smart house prototype and implementation | All above-mentioned tools are required | To evaluate various types of digital solutions in order to combine them and get one smart system | 4 hours |
| | | | **Total laboratory hours:** | **34 hours** |

As it can be seen form the Table 1, in total 9 laboratory assignments were prepared and after completing each assignment, students were expected to reach the intended objectives. Therefore, below will be explained the implemented methodology of achieving these goals.

## 3. Implemented methodology of reaching above-mentioned objectives in the laboratory hours

In the spring semester of 2019-2020 academic calendar, the proposed laboratory assignments were carried out with 3rd year undergraduate group studying the “Control instrumentation and measuring devices” course. There was no any budget allocated for the implementation of these laboratory assignments. It was based on the voluntarily initiative of the lecturers and supported by the administration of State Energy Institute of Turkmenistan. In fact, necessary tools were provided by the institute. Required tools for the laboratory assignments were available for the instructors at the Young scholars' council of the institute.

As per the internal regulations of the institute, the laboratory hours were expected not to include students more than 25 students. Therefore, the group with 20 students were selected as a target group for the realization or implementation of the proposed assignments. Moreover, the amount of tools necessary for the assignments were also limited to this amount of students. The group was divided into 4 subgroups, each consisting of 5 students. Then, each group was informed with intended objectives and goals of the experiments, then students were provided with necessary tools and they were given to the Internet so that students can find out related works or solutions in the Internet as well.

During the project-based assignments, instructors' role was guiding students in using and connecting required tools and assisting them in writing the programming part for the microcontroller. Because students were from technical fields, they had some difficulties in writing the codes for Arduino, therefore, during the laboratory hours, lecturers shortly explained them basics of the C programming and its functions related to the each assignment. Shortly, the instructor served as a mediator who connects students with possible methods of carrying out the experiments. Therefore, the laboratory classes were project-based and student-centred.

A. Objective 1: To describe basics and logics of smart systems, to identify sensors and actuators (2 hours)

This objective was reached in two steps. Firstly, students were shown and explained real-life measuring instruments, implemented smart solutions, sensors, microcontrollers and loads to be controlled. Next, each group was given a name such as “Sensors”, “Loads”, “Microcontrollers” and “Smart systems”. In doing so, in accordance with their group names, students had to explain functions of each device, their working principles and connection diagrams in a written format. For instance, while “Sensors” group described basics and logics of various sensors, “Smart systems” group explained how to construct or create smart systems using required elements. During 2 hours, the name of the groups were shifted to each other so that each group could reach the intended course objectives. After the completion of this step, students had an idea of each part of smart systems individually.

B. Objective 2: To understand working principles of smart systems and to explain logics of designing them (4 hours)

As energy saving is one of the main issues in Turkmenistan (The State Programme, 2018), students are expected to learn energy saving methods during lecture hours. Therefore, in this experiment, they understood how to do so based on smart systems. In fact, using the microcontroller, light dependent resistor (LDR), 5 V relay, bulb and AC power supply, students completed the given assignment, and they worked out an automated system of street lighting in which electrical bulbs are supplied with electrical energy after Sunset while they are switched off after Sunrise automatically. This objective was reached after completing the experiment and formulating the amount of monthly saved energy. There was observed a side effect of the experiment such as awareness of the electrical energy being consumed and thriftiness. After the second step was completed, students now could explain the elements of smart systems as a whole.

C. Objective 3: To implement digital solutions for energy saving and to produce smart systems (4 hours)

After the 2nd experiment, students had an idea about energy saving methods and the logics of designing them. Therefore, in this laboratory assignment, their duty was to find out innovative or digital solutions to save energy in living houses and buildings as it was also indicated in the implementation plan of The State Programme (2018). In order to achieve the intended goals, students carried out the experiment in which they designed smart systems where loads were controlled by motion sensor and thermo-resistor, which are the sources of input signals. In fact, students worked out small projects of automatic control systems where a motor, opening and closing the door, and indoor light bulbs were run by the help of the motion sensor. Moreover, they also designed smart systems where the speed of fan was automatically controlled by using thermo-resistors. By doing so, students' knowledge about microcontroller-based automated systems deepened, they managed to save or cut electrical energy, used for some electrical devices while the energy was not required, and they comprehended the steps and logics of working out smart systems. In fact, they understood that smart systems should contain the microcontroller, loads and sensors or actuators. One group even proposed an innovative way of calculating the heat energy that is being provided to the living houses.

D. Objective 4: To compare different kinds of energy meters and to implement IoT solutions in energy metering (4 hours)

In Turkmenistan, both digital and analogous energy meters are being used. That's why in this experiment, students got acquainted with various kinds of energy meters and compared their working principles. In fact, they had chance to get familiar with 1-phase and 3-phase energy meters being used in Turkmenistan. Moreover, by using ACS712 current sensor, SIM900A GSM/GPRS module and other additional tools, undergraduates were assigned to construct a simple energy meter which also sends an SMS text and other energy-related information to the Internet portal such as “thinger.io” through ESP8266 WiFi module. At the end, students thoroughly compared different kinds of energy meters and implemented elementary Internet-based solutions. In this way, their knowledge about instrumentation and measuring devices had deepened further. Moreover, they had their own profile or virtual room in the above-mentioned internet platform in which they could monitor energy consumption remotely and control the corresponding relay through the internet.

E. Objective 5: To construct water management system and to examine connection diagrams (4 hours)

In Turkmen Nation, there is a saying like “a drop of water is a grain of gold” which points out the nation-wide significance of water management. In this regards, into the syllabus of this course was introduced this experiment which aims to teach students about the mechanisms, connection diagrams and types of water meters. To do this, students of the same group were assigned to construct water management system using YF-S201 water flow meter which operates due to the Hall Effect, a topic which was explained in the theoretical part of the course, i.e., in lecture hours. Students surveyed and found out connection diagrams of the flow meter and necessary programming part from the Internet. In this fashion, objectives of the experiment were met, moreover, the students comprehended the theoretical part of the course and examined various connection diagrams of water meters. Moreover, they came up with the idea that the energy being consumed in order to heat up the living houses can also be monitored and automatically calculated by the help of Arduino-based project. In fact, they proposed that by using double DS18B20 sensors, both water (Twater) and (Toutside) outside temperatures can be measured while the mass of the circulated hot water can be computed by YF-S201 water flow meter. Therefore, the total amount of the consumed heat energy ($Q=m*c*\Delta T$) can easily be calculated.

F. Objective 6: To compare different values of the same physical quantity, to analyse smart systems (4 hours)

As instrumentation plays important role in industry and agriculture as well, the goal of this experiment was to teach students the basics of differential measuring devices which can be implemented in greenhouses. The “humidity of the air” was the physical quantity which would be measured and altered by the help of fans. Therefore, the fundamentals of smart ventilation systems based on differentiation of the physical quantity were explored. To do so, DHT11 temperature and humidity sensors were used together with microcontroller and other required tools. In this way, students learned how to compare the humidity of the greenhouse with the humidity of the air outside the greenhouse. Moreover, after the course, field visit was also organized to show students the instruments already installed in one of the greenhouses. This experience helped them to analyse and compare the different kinds of a device that measure the same physical quantities.

G. Objective 7: To design smart systems and to create digital solutions for daily-life issues (4 hours)

As it was shown and explained in the paper of the authors (Nazarov and Jumayev, 2020), smart alarm system for gas leakages were worked out as a result of the experiments. This device was favourite tool for the students, because there were too many demands to implement this device in daily life in order to prevent any fire disaster that may occur because of gas leakages. The fact that this device is able to send short messages in case of emergency and close the solenoid valve in order to cease the gas supply were sources of motivation for students to further work on the smart systems and create digital solutions that may be used in daily-life problems or issues.

H. Objective 8: To protect electrical devices from over currents and to propose appropriate solutions (4 hours)

The automation engineers should gain skills to overcome any faults or shortcuts which may damage any electrical device or home appliance. In this regards, this experiment aimed to teach them relay protection principles in case of over currents and motivate them to propose appropriate solutions. As they already knew the working principle of ACS712 current sensor and 5 V relay, and their connection diagrams to Arduino UNO microcontroller (Objective 4), in this experiment undergraduates were expected to solve the overcurrent faults in order to protect electrical devices. To do so, they analysed intended maximum electrical currents for each electrical device and prepared the software of the microcontroller. At the end, each group proposed their own solution and they compared them with each other. Some of them used additional tools other than necessary ones. This showed the eagerness and willingness of students to overcome faults that may negatively affect operation of electrical device.

I. Objective 9: To evaluate various types of digital solutions in order to combine them and get one smart system (4 hours)

As one of the main purposes of education is to teach students how to learn the unknown throughout their life, they should be addressed to real-life contexts within the lectures being taught. Gaining any skill is a tough issue. When it comes to the highest cognitive levels of Bloom's taxonomy such as assembling, combining, evaluating, formulating and concluding (Anderson and Krathwohl, 2001), the issue becomes more complicated. Therefore, in this final experiment, undergraduates were directed to the systems which are unions of subsystems. Here, smart house was a good choice where students could evaluate various subsystems and combine them to get the only one complete system. In this way, they would learn how to solve difficult or complex problems by dividing them into smaller parts and then assembling them to find a final solution. To do so, groups were assigned to design a prototype of a smart house where they had to include at least 7 sensors and mini-mechanisms. This assignment yielded fruitful results as students came up with relatively different and quite new ideas.

## 4. Analysis

At the end of the laboratory assignments, in other words, at the end of the second semester of the course, ideas of students were elaborated with a questionnaire, in which they were asked about the effect and appropriateness of the implemented method. Questions were related to the intended course objectives. Followings are the main Yes/No kind questions that were included in the questionnaire:

Q1: Do you think that the aims of the laboratory assignments were clearly explained?

Q2: Did you reach your expectations during the laboratory assignments?

Q3: Did you find the method effective and beneficial?

Q4: Do you think that laboratory assignments were feasible with the course objectives?

Q5: Do you think that the laboratory assignments will be beneficial in your future career?

Q6: Did you enjoy the way course was conducted?

Q7: Do you think that the student-centred learning can be applied to other fields as well?

Q8: Do you think that the teaching methodology has enlightened you in a way that you can make an input in realizing state programmes on digital transformation of economy and education?

Moreover, essay-type questions were also directed to students in order to reveal their ideas and get feedbacks related to the proposed method. From the results or answers of above-listed Yes/No type and essay-type questions, it can be concluded up that for undergraduate students, especially studying in the engineering fields such as automation and control, project-based laboratory assignments are one of best choices as students reach the course objectives on their own pace and the project results make them feel more confident. Undergraduate students stated that throughout the laboratory assignments, they had chance to get familiar with various kinds of sensor, actuators and other additional modules. Moreover, questionnaire results revealed that students stayed more interested in the realization of state programmes related to the digital transformation. However, students also pointed out that such kind of teaching may be suitable only for applied sciences or engineering fields, only if the strategy of carrying out the experiments and their topics are selected appropriately.

In the analysis or evaluation stage, students were also directed written questions in which their opinion on integration of theoretical part with the experimental part of the course was evaluated. They replied that by Arduino-based laboratory assignments, not all theoretical parts of the course were thoroughly explained through experiments, however, they understood that some relevant attributions were made within the laboratory manual.

According to their idea, such laboratory assignments were just an exciting introduction to the automation and control engineering.

## 5. Conclusions

As mentioned before, educating undergraduates of engineering fields is indeed tough and challenging issue. This task demands more attention and in this regards instructors should be addressed appropriate educational methods. In this regards, students, studying in automation and engineering fields, were treated from a different perspective and they were taught using learner-based method integrated with real-life context based approach. Objectives of laboratory hours of "Control instrumentation and measuring devices" course were structured in a way that suits into Bloom's taxonomy going from a simple level to more complex and challenging levels. On first sight, 3rd year undergraduate students found it a little bit difficult to adapt to the new method, however, later they experienced more exciting and learner-friendly environment in carrying out their experiments.

At the end of each laboratory assignment, in order to grade students, it was compulsory for them to write a report about the steps they had followed and laboratory results they had achieved. Moreover, in order to increase reliability and validity of the grading, there were conducted quizes which included both multiple choice and essay type questions. The quizzes, with one-time-access restrictions, were conducted using Moodle platform which was installed in the local network of the institute. As a result, it was found out that 87% of intended objectives were achieved and students were motivated to further carry out research about smart systems and digital solutions. Moreover, some significant points of State programmes and conceptions were integrated into the lectures so that undergraduate students had idea about the priorities of the topics in national level. Students could deal with or tackle the problems they encountered during laboratory hours due to the fact that working with Arduino UNO was easy and user-friendly, as they had access to the Internet in case of any complexity.

While implementing these laboratory assignments, there were some difficulties as well. Therefore, as suggested in SEPT model, extra supports or needs of students were identified. Among them, one of the most significant challenge was that each student had different pace of learning as the concepts of the assignments were new for them. Therefore, in order to foster students to work as a team, encourage self-learning and eliminate gaps between the subgroups, the group was divided into subgroups so that each subgroup contained students with various backgrounds. This also helped to develop their team work capabilities. Secondly, it was difficult to grade the reports submitted after each assignment and measure the level of achievement of the intended objectives. Therefore, students were given concrete instructions in writing reports which were related to course objectives.

It can be summed up that the research or implementation of the new methodology yielded fruitful results. In fact, after these laboratory hours, demand for the participation in Young scholars' council of State Energy Institute of Turkmenistan has increased. By the way, Young scholars' council of the institute is a place where enthusiastic students, with their brilliant ideas, meet and realize their projects under the supervision of instructors. Young members of this council deal with innovative ideas and carry out projects related to smart systems. After the completion of the course, new attendees from these classes came up with new project ideas. Therefore, the study will be deepened further in order to find out appropriate or suitable way of implementing the methodology in different disciplines as well.

## 6. Recommendations

In order to support digital transformation process in Turkmenistan, educational strategies and methodologies should be revised so that undergraduate students can gain digital skills during classes. This can be achieved by using the above-proposed methodology in laboratory assignments. In fact, course objectives should be prepared in parallel with the Bloom`s taxonomy of educational objectives and laboratory assignments should be based on the projects through which students can learn basics of digital solutions, automation systems and logics of microcontroller-based devices. As a result of fruitful laboratory classes, it is strongly recommended that "Control instrumentation and measuring devices" course should be provided with appropriate laboratory assignments in which working principles of sensors, actuators and transducers will be studied by students.

## 7. Limitations

The methodology which is proposed in this article is limited to the technical or engineering courses. Corresponding strategies could be worked out for social or linguistic courses where digital skills are aimed to deliver.

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