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USING ATMEGA 328 MICROCONTROLLER FOR EFFECTIVE STUDENT LEARNING

Use of the latest achievements in the field of microcontroller programming, such as the Arduino platform, allows to qualitatively change the educational process, makes it more intense, increases student motivation, and makes it possible to implement an individual approach, which is important. And this, in turn, improves the efficiency and quality of microcontroller programming. The purpose of this study is to propose an effective methodology for using Arduino Atmega 328 microcontrollers for teaching students and evaluate the effectiveness of teaching programming based on the use of Arduino Atmega 328 microcontrollers based on the Kirkpatrick model. The paper presents a broad review of works that consider the interaction of a person and microcontrollers. In addition, the impact of this approach on the process of learning and teaching is being evaluated. More than 95 students took part in this experiment. First, during the semester, students were taught programming using Arduino Atmega 328 microcontrollers, after which they evaluated this learning. The evaluation was carried out at three levels of the Kirkpatrick model [1], and as a result, the second and third levels showed almost the same results with an error of 3 percent. This study concluded that such teaching methodology is very important in the process of student learning. Interaction and collaboration in the field of microcontroller programming has also been used to introduce non-traditional curricula, including courses in robotics as a tool for addressing the social aspects of robotics and artificial intelligence.

Key words: *programming, microcontrollers, arduino, effectivity, methodology.*

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СТУДЕНТТЕРДІҢ ТИІМДІ ОҚУ ҮШІН ATMEGA 328 МИКРОБАҚЫЛАУШЫСЫН ПАЙДАЛАНУ

Arduino платформасы сияқты микроконтроллерлерді бағдарламалау саласындағы соңғы жетістіктерді пайдалану оқу процесін сапалы өзгертуге мүмкіндік береді, оны көбірек етеді, студенттердің ынтасын арттырады және жеке көзқарасты жүзеге асыруға мүмкіндік береді, бұл маңызды. Ал бұл, өз кезегінде, микроконтроллерді бағдарламалаудың тиімділігі мен сапасын арттырады. Бұл зерттеудің мақсаты студенттерді оқыту үшін Arduino Atmega 328 микроконтроллерлерін пайдаланудың тиімді әдістемесін ұсыну және Киркпатрик моделі негізінде Arduino Atmega 328 микроконтроллерлерін пайдалану негізінде бағдарламалауды оқытудың тиімділігін бағалау болып табылады. Жұмыста адам мен микроконтроллерлердің өзара әрекеттесуін қарастыратын жұмыстардың кең шолуы берілген. Сонымен қатар, бұл тәсілдің оқу мен оқыту үдерісіне әсері де бағалануда. Бұл экспериментке 95-тен астам оқушы қатысты. Біріншіден, семестр барысында студенттерге Arduino Atmega 328 микроконтроллері арқылы бағдарламалау үйретілді, содан кейін олар осы оқуды бағалады. Бағалау Киркпатрик моделінің үш деңгейінде жүргізілді [1], нәтижесінде екінші және үшінші деңгейлер 3 пайыздық қателікпен бірдей дерлік нәтиже көрсетті. Бұл зерттеуде мұндай оқыту әдістемесі студенттердің оқу процесінде өте маңызды деген қорытындыға келді. Микроконтроллерді бағдарламалау саласындағы өзара әрекеттесу және ынтымақтастық сонымен қатар дәстүрлі емес оқу жоспарын, соның ішінде робототехника мен жасанды интеллекттің әлеуметтік аспектілерін шешу құралы ретінде робототехника курстарын енгізу үшін пайдаланылды.

Түйін сөздер: *бағдарламалау, микроконтроллерлер, Arduino, тиімділік, әдістеме.*

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ИСПОЛЬЗОВАНИЕ МИКРОКОНТРОЛЛЕРА ATMEGA 328 ДЛЯ ЭФФЕКТИВНОГО ОБУЧЕНИЯ СТУДЕНТОВ

Использование новейших достижений в области программирования микроконтроллеров, таких как платформа Arduino, позволяет качественно изменить учебный процесс, делает его более интенсивным, повышает мотивацию учащихся, дает возможность реализовать индивидуальный подход, что немаловажно. А это, в свою очередь, повышает эффективность и качество программирования микроконтроллеров. Цель данного исследования – предложить эффективную методику использования микроконтроллеров Arduino Atmega 328 для обучения студентов и оценить эффективность обучения программированию на основе использования микроконтроллеров Arduino Atmega 328 на основе модели Киркпатрика. В статье представлен широкий обзор работ, рассматривающих взаимодействие человека и микроконтроллеров. Кроме того, оценивается влияние такого подхода на процесс обучения и преподавания. В эксперименте приняли участие более 95 студентов. Сначала в течение семестра студентов обучали программированию с использованием микроконтроллеров Arduino Atmega 328, после чего они оценивали полученные знания. Оценка проводилась на трех уровнях модели Киркпатрика [1], в результате второй и третий уровни по-

казали практически одинаковые результаты с ошибкой в 3 процента. В этом исследовании сделан вывод, что такая методика преподавания очень важна в процессе обучения студентов. Взаимодействие и сотрудничество в области программирования микроконтроллеров также используются для внедрения нетрадиционных учебных программ, в том числе курсов по робототехнике как инструмента решения социальных аспектов робототехники и искусственного интеллекта.

Ключевые слова: *программирование, микроконтроллеры, Arduino, эффективность, методология.*

1. Introduction. Over the past few years, we have seen a huge need for educational systems to equip students with competencies that are increasingly required in the labor market [2], such as innovation, collaboration, problem solving, critical thinking and digital literacy [3]. This encourages academic institutions to work on approaches to teaching and learning, to promote the development of such competencies, and to promote pedagogical innovation and digital learning [4] Microcontroller lesson material is needed in order to improve students' readiness to work. Almost all equipment in the industry has used automation in the production process. Meanwhile, to study microcontroller material better, microcontroller trainer media is needed. Currently, Arduino is one of the most convenient platforms for developing control devices on microcontrollers [5]. The Arduino board contains: Atmel's ATmega microcontroller, reset circuits, a quartz resonator, a built-in power supply voltage stabilizer, a USB adapter that provides communication with a personal computer, a built-in programmer, tools for in-circuit programming [6]. Arduino's programming language is based on C/C++, but has a simplified syntax and is relatively easy to learn [7]. The Arduino platform makes it relatively easy to develop applications based on AVR microcontrollers and has a number of advantages over other platforms in terms of learning and mastering the technology of developing microcontroller devices: Low cost; Cross platform; Simple and clear programming environment; Extensible open source software; Arduino modules are expandable hardware with open circuit diagrams [8].

The above advantages can be decisive when choosing an object of study and research, study and research of development technologies based on microcontrollers with a limited time volume of training courses on microprocessor technology [9]. Such time limitations are typical during the transition to a bachelor's degree, as well as for specialties in which electronics and microprocessor technology are introductory courses. It is necessary to indicate one more distinctive feature of the Arduino platform in terms of use in the educational process. This is relatively cheap compared to industrial "brand" laboratory equipment. For example, the NI MyRIO-based laboratory setup from National Instruments [10] relies on the Lab View software environment. The cost of NI MyRIO with the Lab View software environment, depending on the composition of the modules, can reach several hundred thousand rubles [11, 12]. The Arduino board is ideal for the first steps in this area, because has a compact size and simple circuitry.

2. Literature Review. The use of microcontrollers in the education process, not only for students of computer science, computer engineering and related specialties, but also for physicists, chemists, mathematicians, networkers and others [13] is one of the most necessary in the modern educational environment [14]. From the basics of the electromechanical device of modern digital devices to the level of the assembler of these devices, programming both individual components [15] and the entire device based on visual aids and debug-

gers allows the student to gain valuable practical skills and abilities that are generally aimed at systematization of knowledge and skills. It is also important to note the widespread use of Arduino microcontrollers not only in higher education institutions, but also for teaching senior students of secondary schools, gymnasiums, lyceums, as well as colleges.

Learning using microcontrollers for a teacher can be accompanied by a number of problems, such as installing an accompanying programming platform, mastering a programming language, a large array of sensors and circuits on a board, teaching methods [5] and presenting educational material.

The use of Arduino Atmega 328 microcontrollers allows the student to understand the real situation in the context of circuits, experiment, invent, make mistakes, correct mistakes. Although the process of real-world context to microcontroller context may be accompanied by some problems of learners [16], in the process of sequential learning they can be overcome.

In teaching programming in laboratory classes, the results of a 2021 study by [17] showed that students as interesting and exciting characterized the use of Arduino microchips. A survey was also conducted, the results of which revealed that microcontrollers have a visually positive effect on the perception of educational material. In general, this and many other [18] studies confirm the importance and interest in using Arduino Atmega 328 microcontrollers among students. The formation of design competence is implemented with strict consistent implementation of the instructions of the rules for working with microcontrollers.

An analysis of the effectiveness of the Arduino Atmega 328 microcontroller was carried out in the work of [19]. The magnitude of the effect obtained was more than 60%, which confirmed the effectiveness of using these devices. Features such as the type of school, the presence of a course in the curriculum, the peculiarity of the student, the chosen programming language, the time of study, the number of hours per week and the contingent of students were taken into account in the calculation of efficiency. However, it is important to note that this study was conducted in schools, among students.

The importance of using microcontrollers is also noted in higher education institutions. For example, Arduino has been used in a biological analysis process for glucose detection [20], in information security tasks, in a security and energy efficient home automation system, as well as data logging related to solar panel use . Arduino has also been used in weather monitoring, in gesture control, it was integrated into the digital signal processing system from the well , as well as IoT-based air quality monitoring using Arduino sensors and MQ series with dataset analysis.

3. Research method. The purpose of this paper is to describe the methodology of using Arduino Atmega 328 microcontrollers for effective student learning. To achieve this goal, the following tasks should be performed:

1) To justify the choice of the necessary programming languages for their step-by-step study from the point of view of the simplicity of their development and at the same time the completeness of functionality for use in robotics;

2) Give recommendations on the study of microcontrollers of the software element base at the university.

This device contains at the same time a microcontroller (usually from Atmel), a programmer, a quartz resonator, a power stabilizer, and much more that is necessary for

comfortable use. This device is programmed from the USB port. For Arduino Atmega 328, there is a special development environment Arduino IDE, written on the Java virtual platform. The Arduino IDE has a C++ dialect that will make it easier for the student to understand. Arduino IDE is a free environment. The authors of the article consider it the most relevant for today's application for teaching students.

Arduino serves to solve one difficult problem; it is how to teach students how to create electronic devices. Arduino is a flexible tool for designing automated and automatic control systems at the physical and software levels [15].

4. Materials and methods.

4.1 Research context. This study was conducted at the Faculty of Information Technology of the Kazakh National University named after al-Farabi for 3rd year students of the specialties "Computer Engineering" and "Computer Engineering and Software". The program of the course with the optional component "Design and Embedded Multiprocessors" implies 1 lecture and 2 laboratory classes, in total 45 hours or 5 credits. Training and research was carried out in the laboratory of "Intelligent Programmable Systems" for 5 years. The prerequisites of this course are the disciplines "Physics", "Integrated Circuits". Participants of the study, 3rd year students who do not have experience with Arduino microcontrollers. Teachers are concerned about the effectiveness of using microcontrollers, namely Arduino, assessing the work of a teacher based on student surveys, student performance and the process of developing education.

4.2 Procedures. The effectiveness of training using Arduino microcontrollers was carried out on the basis of the classical approach is the Kirkpatrick model. The four-level model contains the following steps: learner's reaction or learners opinion and feelings about learning; learning is an indicator of the growth of education and skills; behavior is improvement of skills and abilities, usually based on the assessment of the teacher; the result is the effect of learning.

All of these measurements are recommended for a complete and meaningful assessment of the learning process. To implement the assessment, a study was conducted based on a survey of students. The questionnaire consists of 20 questions assessing response and learning, that is, the first three stages of the Kirkpatrick model. 95 students took part in the survey, Table 1 shows the characteristics of the surveyed groups.

Questions for the survey were compiled on the basis of a review of a large volume of research and analysis. For this study, the 2 stages of the Kirkpatrick model are more informative and important. Therefore, the main part of the questions was compiled in these two sections. Several questions are devoted to determining views on the accessibility of the course: understandability, complexity, importance in the future, novelty, competence of the teacher. Further, it is proposed to evaluate the relevance, applicability, organization of the educational process on a scale. The rating scale consists of 5 points. Participants anonymously, in an independent form, could mark the necessary points.

The next group of questions is devoted to assessing the acquired theoretical knowledge and practical skills on the basis of multiple choice test questions. This group of questions is based on three levels of difficulty: easy, medium and difficult questions. Easy options contain, for example, questions to test knowledge of the name of the components of the Arduino board, followed by questions to determine the knowledge of the function

and their capabilities, and complex questions, mainly with mathematical and physical calculations.

Further, the implementation of the third stage of the Kirkpatrick model took place on the basis of the teacher's assessment for three boundary controls of the academic semester. The maximum score that a student could receive abroad is 100%, that is, three milestone weeks make up 300%, where scores above 70 indicate good mastery of the material, and above 90 indicate excellent academic performance. According to statistics, about 25 thousand visually impaired citizens live in Kazakhstan, so it is very important to make it clear to students that there is such a problem and, most importantly, it can be eliminated.

5. Results. All respondents found the content of the course to be very simple and understandable. Moreover, 50.5% of the respondents rated this item on a five-point scale at 4 points, and the rest 49.5 percent at 5 (Fig. 1). That is, the students had practically no problems in mastering the course.

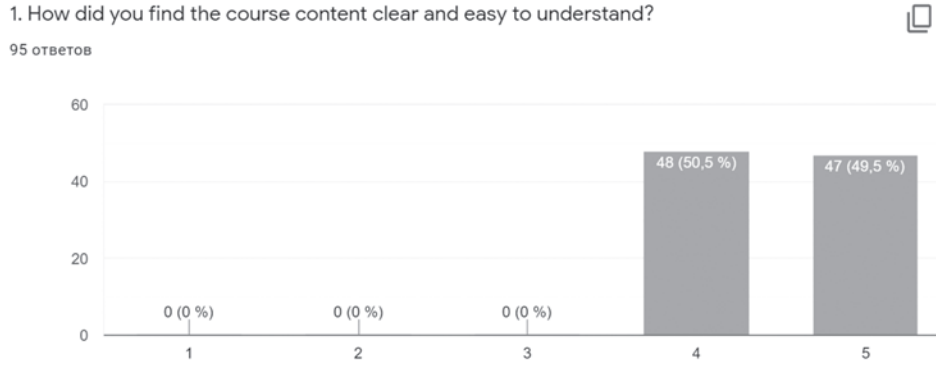

Figure 1 – Evaluation of comprehensibility and simplicity of the course

The following questions to assess the relevance and applicability of this course showed very good results, almost all respondents (98.9%) believe that the proposed course is relevant and the knowledge gained from the course can be used in production (Fig. 2).

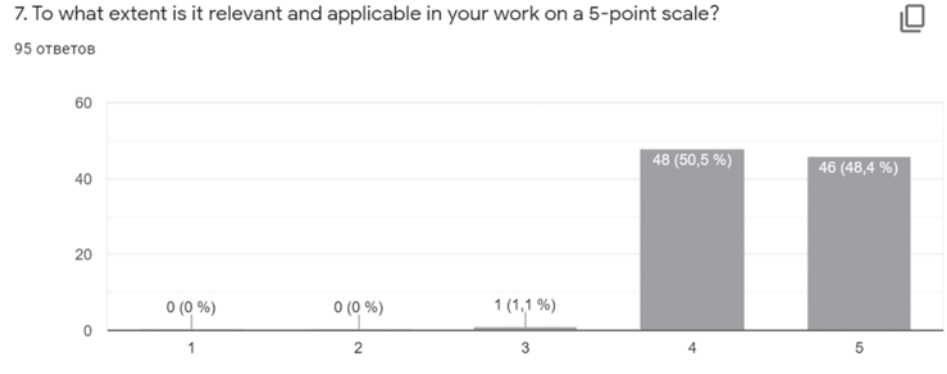

Figure 2 – Relevance and applicability of the course

The organization of training received a rating of four points from 22.1% of respondents, when 7.9 believe that this item deserves the highest rating (Fig. 3).

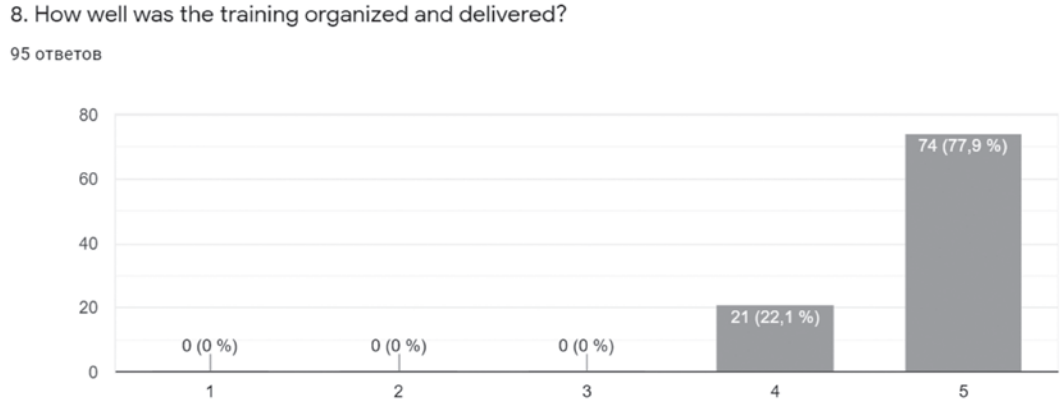

Figure 3 – Evaluation of course organization

Interesting suggestions were made by learners to improve the course content. More than 50 percent of students suggest adding more practice tasks, while 32 percent believe that no improvement is needed, the rest answered that they were satisfied with all the content (Fig.4).

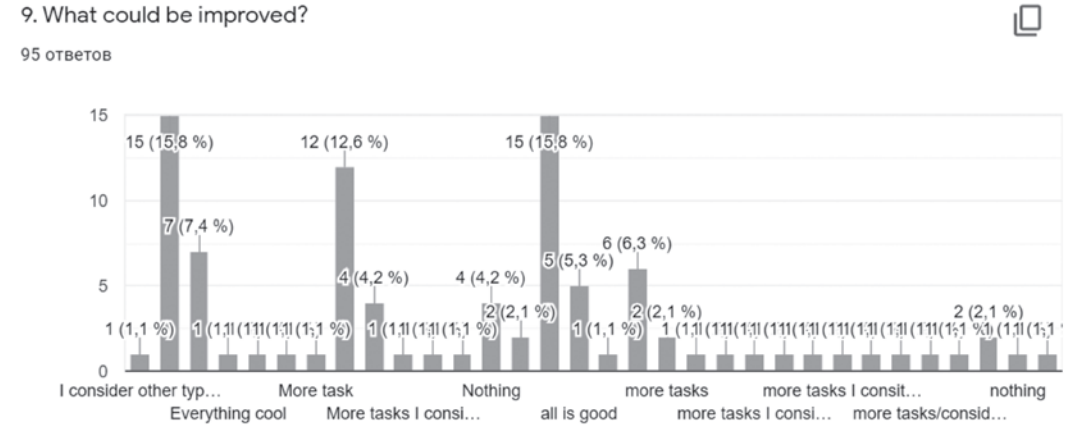

Figure 4 – Participants' proposals

Further, test questions were organized to assess the knowledge gained and progress in this kus. On average, students showed excellent results on test questions. More than 93.7 percent of those surveyed showed excellent results.

The assessment of the teacher and the assessment of the testing conducted, in principle, showed the same results. The error was only 3.17 points (Fig. 5).

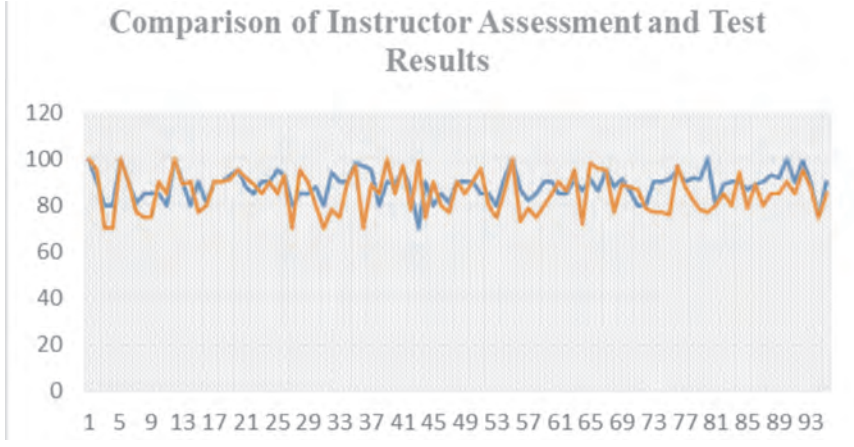

Figure 5 – Instructor evaluation

6. Conclusion. This article discusses one of the methodology for teaching students programming based on the use of Arduino microcontrollers. The work on the article was aimed at sharing the experience gained over several years of teaching students the basics of programming. In the practical part, it was interesting to observe the development of the material, the receipt and interpretation of the results that they received.

In general, this study is the beginning of further study of the process of teaching students using not only Arduino microcontrollers, but also other types. The results obtained showed that this type of integration had a good effect on student satisfaction, however, further intensive development of information technology requires the same progress from the educational process.

Understanding the principles of operation of microcontrollers is the basis for the effective professional activity of specialists in this area. The solution to this problem can be the use of the Arduino debug board in the process of teaching students of the specialty 5B071900 - Radio engineering, electronics and telecommunications, 6B06103 - Computer engineering, 5B070400 - Computer engineering and software programming microcontrollers.

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