(Online) ISSN 2712-0554
Original Research

Heritage and Sustainable Development
Vol. 8, No. 1, 2026, pp.485-498
https://doi.org/10.37868/hsd.v8i1.1325

Training digital development skills for engineers: Experience from student projects in forest industry

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Received May. 21, 2025
Revised Mar. 27, 2026
Accepted Apr. 15, 2026
Online Apr. 22, 2026

Abstract

Today, employers impose new requirements on graduates of higher engineering education institutions: a graduate must be able to learn quickly in the workplace and easily master modern production equipment. Educational programs of higher institutions do not always keep up with the development of modern technology, and laboratory equipment does not always correspond to the modern level. The article presents the Petrozavodsk State University's experience in involving students of engineering and natural science major in the project activities connected with the creation of educational laboratory equipment with microcontroller control as part of their coursework and final papers. During this pedagogical experiment, the influence of non-IT students' work on three projects related to solving IT problems in the forestry industry on their preparation for future professional activities was studied. The task of this student's projects work was not so much to update the laboratory fleet, as to teach students through designing and creating real products within the framework of student projects and to study the impact of project activities on the overall learning outcomes of the involved students. As a result of project activity students not only gained new knowledge and mastered new competences, but gained skills of teamwork and interaction in the team, and also intensified their interest in learning activities in the main disciplines of their major, realizing the ways of applying the knowledge gained at the university to solve real engineering problems.

Keywords: Education, Interdisciplinary competencies, Training laboratory equipment, Microcontroller, Project activities, Non-IT students

1. Introduction

After successful defense of a diploma project, engineering students find themselves in the highly competitive labor market, where employers place high demands not only on theoretical knowledge of a graduate, but also on practical skills and competences. The goal of an educational institution is not only to transfer knowledge to the student, but also to make the student a competitive and in-demand specialist. Unfortunately, for objective reasons, educational institutions cannot keep up with the requirements of employers, since it takes at least four years from the time a student enters the university on a qualified educational program to graduate. Therefore, education curricula do not always meet the requirements of the labor market, and, in addition, the graduate does not have experience in engineering positions and solving real engineering problems. Thus, Manuel Salas-Velasco points out [1] that engineering graduates often occupy positions at the first place of work that do not correspond to the level of education received at the university, and sometimes even to the specialty, but, after gaining practical experience, within several years, they get a position corresponding to the level of education. Thus, after graduation a graduate needs a certain amount of time to adapt to employment and training at the workplace.

As representatives of IGIP (International Society for Engineering Pedagogy) noted in their report [2], in today's rapidly developing world the volume of technical information doubles every two years, new engineering disciplines appear, new tasks appear within traditional engineering, and the modern specialist should possess interdisciplinary knowledge and skills. Thus, engineering training cannot be limited to a higher education institution - the roots of future engineer training should be laid as early as at school, and after graduating from a higher education institution an engineer should be ready to engage in self-education during all career [3]. Therefore, an important task of a university is to "teach how to learn" so that after receiving a diploma a young specialist could independently obtain or update the knowledge required at a particular workplace.

It is important for students to acquire not only technical knowledge and skills, but also strong "soft skills" competences for their future successful professional activities. The importance of "soft skills" development for a graduate's successful career is indicated by many research [4], [5]. These competencies are also important for a future engineer, since today an average engineer spends more working time on interaction with other employees and specialists than on technical engineering activity itself [2]. Therefore it is extremely important for a student to gain experience in teamwork, to try himself as a project leader and customer, to practice asserting his point of view, to have an opportunity to show initiative in the professional field and to develop creative thinking, to learn how to plan, train self-organized and manage time, to gain communication skills not only with students, but also with university professors and masters of the educational-production center during his studies at university. Thus, the importance of students' extracurricular activities, which allow successfully developing “soft skills” competences, for fast employment and successful career in the future, is indicated in the research conducted on the example of University of Southampton graduates [6].

Petrozavodsk State University has accumulated some experience in involving engineering and natural science students in projects on creating educational laboratory equipment with microcontroller control. The article presents the students' work results and analyses the impact of project activities on the students' overall learning outcomes. In the context of this study, by "soft skills" we mean personal attributes and social attitudes that enable students to interact effectively with others in a workplace environment. By "interdisciplinary competencies" we mean integrating diverse knowledge to solve complex, interrelated modern engineering and technological problems. By "project activity" we mean the purposeful creative and productive activity of a student or group of students aimed at solving a specific applied problem under the guidance of a teacher.

The paper describes the experience of working with three students' projects on the laboratory training unit's creation. Thus, the main goal of the pedagogical experiment was to study the mastering conditions by non-IT students' skills related to the production IT-sphere when carrying out their projects. To achieve this goal, the following research objectives were formulated: to justify the optimal number of students; to select research objects that allow developing skills in creating IT-objects.

1.1. Digital development skills required in forest industry

At the "Forest, Mining and Building Sciences Institute" of Petrozavodsk State University students graduate in the education fields "Technology and Equipment of Logging and Woodworking" and "Forestry". Graduates of these directions, mainly, work at the enterprises of timber industry complex. Russian forestry specialists understand that in the near future informatization and digital technologies will be increasingly actively implemented in the forest industry, including the processes of logging, timber processing and reforestation. Thus, the Strategy for the Development of the Forestry Sector of the Russian Federation until 2030 [7] notes that it is necessary to develop automation, robotization and introduce "breakthrough" digital technologies in the forestry industry. At present, numerically controlled machines are widely used at the enterprises of the timber industry [8], [9], a variety of automated equipment is introduced, and digitalization of production is actively going on [10], [11], and forest machines are equipped with onboard computers [12], [13]. Machines and equipment must be properly operated, maintained, and upgraded. However, graduates are not sufficiently prepared to work with modern equipment. Of course, students study such disciplines as "computer sciences" and "electrical engineering sciences", and in addition actively use personal computers in specialized disciplines, but students lack the skills to work with modern equipment, and in the education curricula there is no practice-oriented discipline, where students could get acquainted with the basics of automation simple, but real production processes.

The Ministry of Science and Higher Education has been discussing for quite a long time how to solve the problem with insufficient IT skills of university graduates. If earlier the introducing a mandatory IT module possibility for students was even discussed, now additional knowledge in the IT is planned to be imparted to students as part of additional professional retraining at special "Digital Departments" being created in universities. According to educational standards, during the training process, students in the education fields "Technology of logging and wood processing industries" and "Forestry" should acquire work skills of modern technologies application in their future professional activities. The competencies in educational standards are formulated in a general form, and this gives freedom in their implementation during the educational process. Based on the structure and scale of enterprises in the forest industry complex, it is possible to assess their needs for competencies in modern information technologies.

Large enterprises (pulp and paper mills, plywood and board enterprises, sawmills with a capacity of over 100 thousand cubic meters) do not require an employee-technologist to have advanced knowledge of the equipment hardware part, and mainly impose requirements on control programs knowledge and the ability to effectively use them in managing the technological process. Medium-sized enterprises (mainly sawmills with a capacity of 30 to 100 thousand cubic meters, furniture factory), depending on the organization of the technological process, the equipment variety and the number of personnel, occupy an intermediate position – personnel of various levels of training, with broad requirements for technical outlook, the need to understand the relationship between the equipment control systems and technological machines. Small enterprises – sawmills, woodworking (with a capacity of up to 30 thousand cubic meters, furniture). A small machines number and a small personnel number require a thorough knowledge of the technology processes, both in the hardware and software part.

The widespread introduction of CNC machines, especially in medium and small woodworking enterprises, requires a wide range of skills in working with such equipment, not only mechanical but also electronic components. In our opinion, the greatest effect in mastering modern information technologies for non-IT students can be achieved by project activities on a topic combining their study area and IT.

2. Research method

The main method was a pedagogical experiment. The "Technology and Equipment of Logging and Woodworking" and "Forestry" students were involved by the teachers in the project activities aimed at the laboratory training unit's creation with microcontroller-based system control, which solving the saturation problems of the university laboratories with new educational equipment.

Project activity is a special pedagogical technology that allows students to independently acquire knowledge and competences because of solving a certain practical task under limited time and resources conditions.

Modern project activities are based on the project method developed by William Herder Kilpatrick [14]. Nowadays, similar methods are effectively used in engineering education [15], [16]. From the point of engineering education view, the result of project activities should be a product or a machine.

Involvement of "Technology and Equipment of Logging and Woodworking" and "Forestry" students in extracurricular project activities allows solving the above-mentioned engineering education problems. The project is carried out by students outside the approved curricula, which allows the project to solve new and interdisciplinary problems, as well as to respond flexibly to employers' wishes. Since the goal of the project is a certain product or machine, students must solve real engineering problems and gain practical skills in designing, constructing, assembling, programming, etc. in the project implementation course. Independent work of a student or a team of students on a project allows them to effectively develop their soft skill competences.

Students were selected for the project on a voluntary basis. The invitation to participate was announced to students in training sessions at the beginning of the academic year. The students who responded received more detailed explanations; they were introduced to educational projects implemented by senior students in previous years. Further work with students who showed interest in project activities took place as part of the student's independent work and additional consultations with teachers. Students received tasks that involve the automated control systems creation, which allowed students to practice worked with microcontrollers, sensors and actuators, master at the basic level of programming and assembly of the electrical part of the installation using the soldering process. Students had access to the university laboratories and workshops and, if necessary, received assistance from the faculty and production center engineers. To implement the project, students received material resources directly from the university or the project was created using grants that were won by the students. Observation of the students during the project's implementation allowed to evaluate the students' work on the project itself, as well as the effectiveness of the project method for the purpose of students' educating and gaining practical skills, development of their professional and soft skill competences.

The automation objects were chosen from the forest industry, with which the students are already familiar – they have listened to the theoretical course, have done laboratory work or work placement internship. The projects participants were formulated educating tasks to be solved in their work course. Materials and equipment for project implementation were presented. Working meetings with the university departments responsible for certain aspects of project implementation were held.

When implementing the pedagogical experiment, the authors followed a methodology consisting of five stages:

At the first stage, students were offered a project topic that was of interest to both students and the department of teaching staff. The topic should be relevant, interesting, and the tasks to be solved in the project should be implemented by students in one or, at most, two years. At the second stage, working groups were formed from interested students. The authors consider that it is most effective to create groups of 2-3 students, and even if during the project implementation one of the students for some reason cannot work on a project, the rest of the group could complete the project. At the third stage, with the teachers' help, tasks were formulated, the consistent solution of which would allow students to implement the project. Each task was necessarily analyzed in detail, and it was planned what material and labor resources should be involved. At the fourth stage, students solved the assigned tasks. If necessary, teachers joined in to help the student group. As a result of the fourth stage, a technical product was born. At the fifth stage, students presented the results of their work and prepared reporting documentation.

3. Results

The Arduino hardware platform was chosen as the main product to implement a microcontroller-based control system for the laboratory training units developed by the students. Today, Arduino-compatible boards are widely used around the world for research and teaching projects. The Arduino platform popularity is due to the openness of the Arduino project, the affordable price, the wide range of compatible sensors and expansion boards, many ready-made libraries, a friendly user community and the cross-platform software [17], [18]. The Arduino platform is used not only to teach programming and robotics, but also to train various engineering and science fields for students [19], [20], [21].

In Russia the Arduino platform is also very popular and, for example, is widely used in school supplementary education in robotics and programming camps [22], [23], but school students after such camps usually enter physics-technology and mathematics fields of educations. Therefore, the students of "Technology and Equipment of Logging and Woodworking" and "Forestry", who participated in the project activity, although they had heard about the Arduino platform, but they did not have strong skills in working with the Arduino. All projects were implemented in the 2020-2023 academic years, during the 3rd- 4th year of undergraduate studies of "Technology and Equipment of Logging and Woodworking" and "Forestry." The projects are implemented as part of the student's independent work, which is included in the curriculum. Students who participate in project activities use the time allotted for independent work more fully and in a diverse way.

3.1. Wood drying chamber

The goal of the first project, implemented by the "Technology and Equipment of Logging and Woodworking" education field for students was to create laboratory equipment for studying the wood drying process. The students worked on this project as part of their final qualification papers. Knowing the wood drying physical principle is important for future engineer-technologists. The university laboratory has tools for determining the moisture content of wood by direct and indirect methods. An ordinary drying oven was used as drying equipment for direct moisture content methods, but the drying oven is not very well suited for studying drying processes.

The relevance of the student's work in this area was not in doubt, since the country is actively promoting the direction of deeper wood processing, which usually implies the need to dry wood from natural moisture to carpenter's moisture. A second-year master's student worked on the project as the main executor, and a fourth-year bachelor's student joined him to help at some stages. The schematic diagram of the laboratory unit and the electrical part appearance of the project is shown in Figure 1.

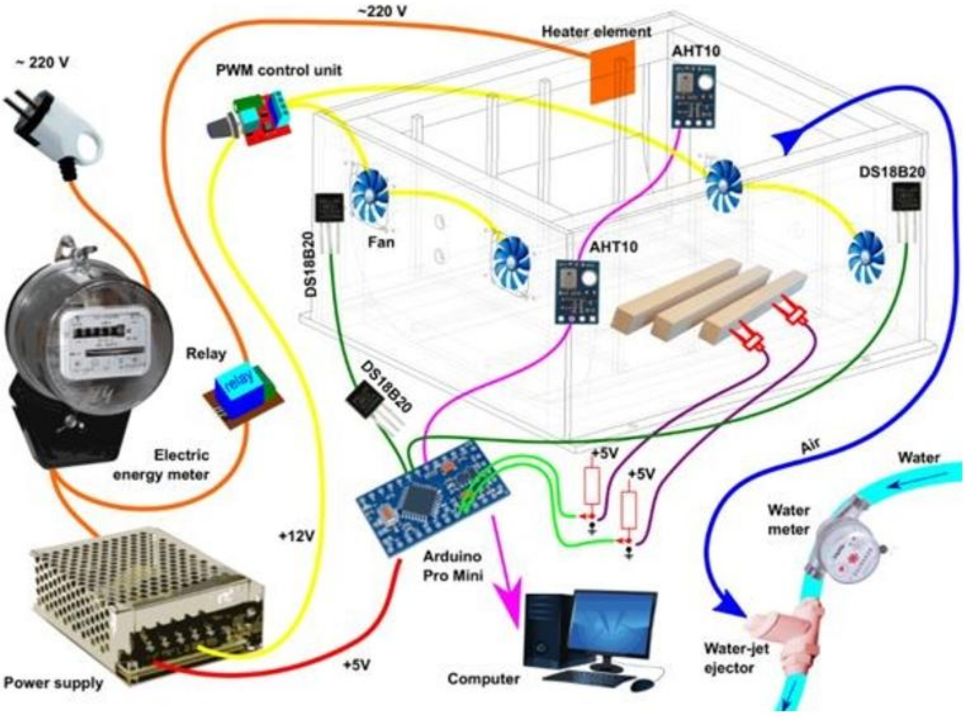

Figure 1a. Schematic diagram of laboratory unit for studying wood drying processes

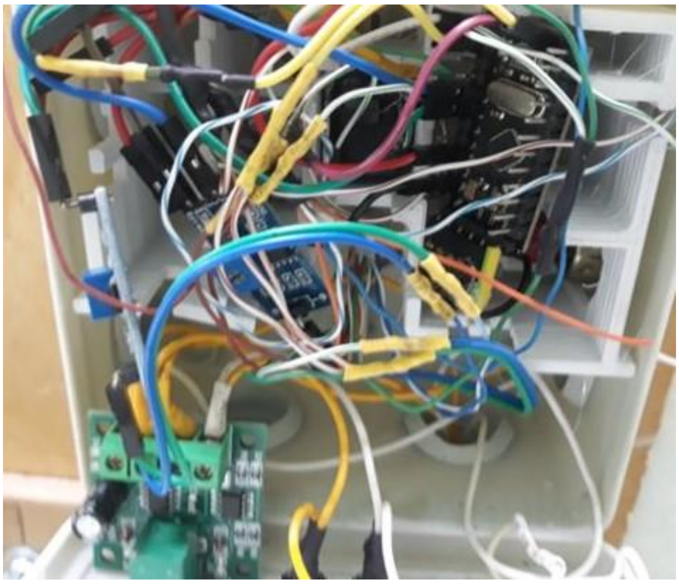

Figure 1b. Laboratory unit for studying wood drying processes: electrical part of the compact drying chamber

The university provided the students with workshops and funding to purchase electronic components. The laboratory unit is a compact drying chamber, where the parameters of the environment and the dried material are constantly monitored. To monitor the wood drying process in the body of the laboratory unit was installed a sensors system: sensors of humidity and air temperature inside the chamber (AHT10), sensors of wood sample temperature and laboratory air temperature (DS18B20), and to assess the humidity of wood sample used two-electrode probes from iron needles (indirect conductometric method of moisture assessment). The Arduino Mini Pro is used as a controller to collect data from sensors. The data from Arduino are transferred via a USB-TTL converter to a personal computer, where they are recorded in a text file on the hard drive.

To heat the compact drying chamber interior space, infrared film elements on the cover and in the housing which are powered from AC 220 V are used. To reduce heat loss, the housing and cover were insulated. The assembled unit appearance is shown in Figure 2. Thus, during the work on the project students had to study scientific and technical literature, to study the theory of wood drying more deeply, as well as to apply theoretical knowledge gained during theoretical training to solve a real engineering problem: to design a 3D-model of the compact drying chamber using CAD-program; to conduct strength and heat loss through the enclosure calculations; to produce parts using wood-working machines; to assemble and insulate the housing of chamber; to mount electronic components in the housing; to test the laboratory unit.

Figure 2. General view of the laboratory unit for studying drying processes

Before the project, the students had no experience in working with microcontrollers and assembling electrical circuits and did not know how to sell them. However, while working on the project with the help of teachers, they learned the basics of microcontroller control and got necessary skills for assembling control circuits and writing control programs for taking readings from sensors. As a result, the students who worked on the laboratory unit for studying drying processes successfully completed and defended their final qualification works, presenting in them the results of design activity and drying chamber acceptance tests. At the moment it is planned to use this laboratory unit for the research work of junior students.

3.2. Wood cutting laboratory unit

The idea of creating a laboratory unit for learning wood cutting processes was born during a discussion with students about the difficulty of studying wood cutting theory. The one student volunteered to work on the idea and proposed the future laboratory unit concept, which was submitted to the competition and received grant support.

In implementing this project, all five stages of the applied methodology can be noted. The chosen topic was interesting to both the students and the department teachers. The project relevance was confirmed by winning the students' grant competition. Although the creation of a student group of several people was not required under the terms of the grant and there was only one main performer, a team of interested students and teachers nevertheless formed around the project. To achieve the project goal the following tasks were formulated: design of the installation frame; calculations of the frame elements for strength; frame manufacture and electric drives assembly; a control system creation; the laboratory unit testing; preparation of reporting documentation for the grant and the results protection. According to the grant terms, the project was implemented for two years. A successful consistent solution to the tasks set made it possible to implement the project.

The laboratory unit allows to fix a wood sample and to cut it with different interchangeable cutting tooth, measuring cutting forces under varying conditions: the wood species, woods humidity, the shape and angle of the cutting tooth, as well as other parameters. The cutting tooth is guided on a profile rail that is fixed to the beam. The cutting depth of the cutting tooth is set by raising and lowering the beam with two stepper motors. To drive the cutting tooth a DC motor from a car interior heater rotates the lead-screw shaft of the screw-and-nut transmission. The motors are controlled by an Arduino UNO through L298N drivers and KY-019 relay modules. The cutting force of the wood sample is recorded by strain gauges, which are connected to the Arduino UNO controller through three HX711 analog-to-digital converters, and additionally the DC motor supply current is monitored through an ACS712 current sensor. The data from the sensors are transmitted to a personal computer, where they are visualized by means of a program on FreePascal (Lazarus). The schematic diagram of the laboratory unit for studying wood cutting is shown in Figure 3, and the appearance of the unit on Figure 4.

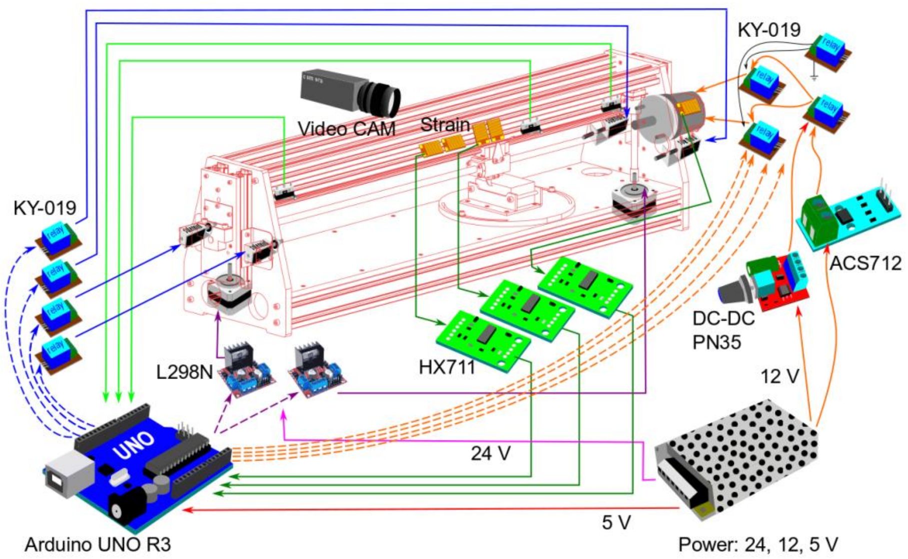

Figure 3. Wood cutting laboratory unit schematic diagram

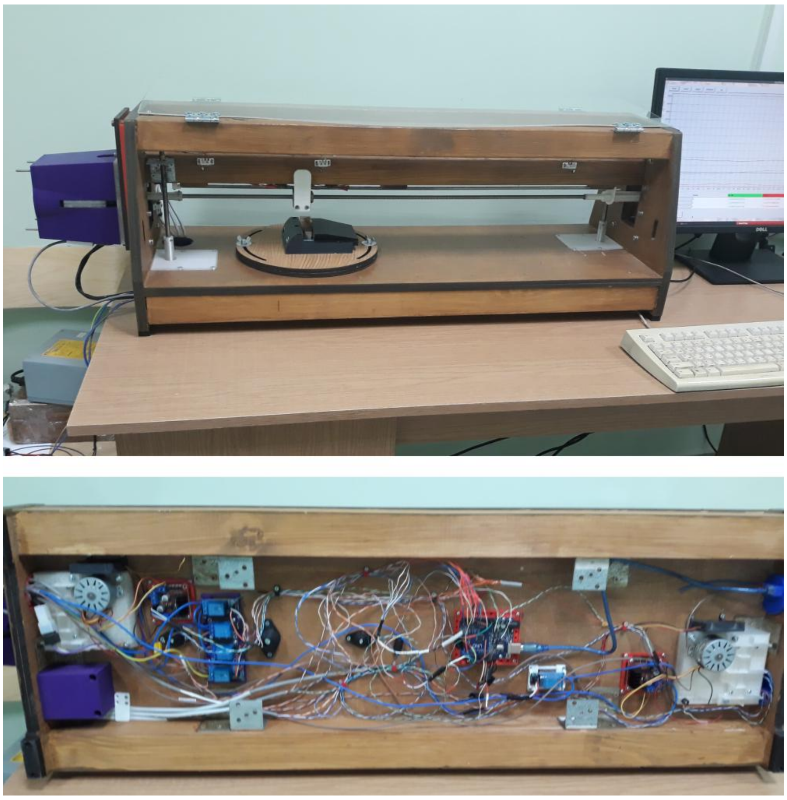

Figure 4. Appearance of the unit for the wood cutting processes study

Working on the project was not easy, because the student had no experience with microcontrollers, assembly of electrical circuits, as well as the student did not know how to solder. The student figured out the basics of microprocessor control, learned how to solder for control circuit assembly. The student had to interact with the university specialists who helped write programs for the microcontroller and personal computer. In addition, while working on the project the student understood the wood cutting theory, learned new skills, and applied his design practical experiences: he designed the unit details in CAD-program as 3D-models and did strength calculation of the beam joint with profile rail and cutting tooth. While working on the laboratory unit student used modern equipment – a laser cutting machine, where the unit body elements were cut out from plywood according to the design drawing and 3D-printers, where many parts and assemblies, including gearboxes with cylindrical gears, were made by additive technologies. When working on the project, the result of intellectual activity was formalized – the student together with the teachers received a patent for an industrial design [24]. The student successfully completed his master's degree, using the developments on the laboratory unit for the cutting processes of study as the basis for his master's graduate qualification work. Currently, the laboratory unit is used as a working exhibit when conducting vocational guidance for schoolchildren.

3.3. Germination table for tree seeds

The project was implemented by a group of third-year undergraduate students in the "Forestry" education field. The aim of the project was to create a universal table for the tree seeds germination which in one unit implemented different germination methods and could be transformed into a training greenhouse. The project idea arose since the department had only non-automated equipment for germination of seeds. The use of which is very labor-intensive and automated industrial equipment is too large for classrooms and very expensive. Students with the creating a universal table for germination ideas in a grant competition and won it, receiving support for the project implementation.

The implementation of this project can also be divided into five stages. The project topic was interesting to the students and teachers. A working group was created by the students who showed interest. With the teachers help the project was divided into tasks: designing the table for germination body; creating the body; equipping the body with sensors and actuators; writing software; testing the table for germination; preparing reporting documentation and defending the project results. Consistent with this task solution allowed the project to be successfully implemented.

The universal germination table design is a pool of water, which is heated by a tubular electric heater. Above the pool there are seed beds and growing trays. Phyto-lamps for lighting the seeds or plants are suspended from the top. Plexiglas enclosing structures are used when converting the table into a greenhouse. As there are a lot of sensors and actuators in the universal table, the Arduino MEGA board based on ATmega2560 was used as a controller in the project. The unit uses the following sensors: water temperature – DS18B20, light – TEMT6000, air temperature and humidity – DHT22, soil moisture – YL-69+YL-38, and water level sensors of original design. As actuating member are tubular electric heater, phyto-lamps, fans and servomotors for ventilation, when the installation is used as a greenhouse, as well as servomotors for venting, irrigation pumps, and a separate pump to maintain water level in the pool. The germination table is managed from the control panel, which is equipped with buttons, a variable resistor, and the control of work is carried out through the inscriptions on the control panel screen. The table can be connected to a personal computer, then the values of the sensors are stored on the computer hard drive, and from the computer you can control the table for actuating members. For fire safety, the water level and water temperature sensors are duplicated, and in addition, a safety system independent of the controller, triggered by a thermistor of an electric tube heater or a water sensor, has been implemented. To ensure electrical safety, 220V and low-voltage voltages were separated – the elements are in different terminal boxes with at least an IP55 protection class. A principle schematic diagram of the germination table is shown in Figure 5, elements of electrical part on Figure 6.

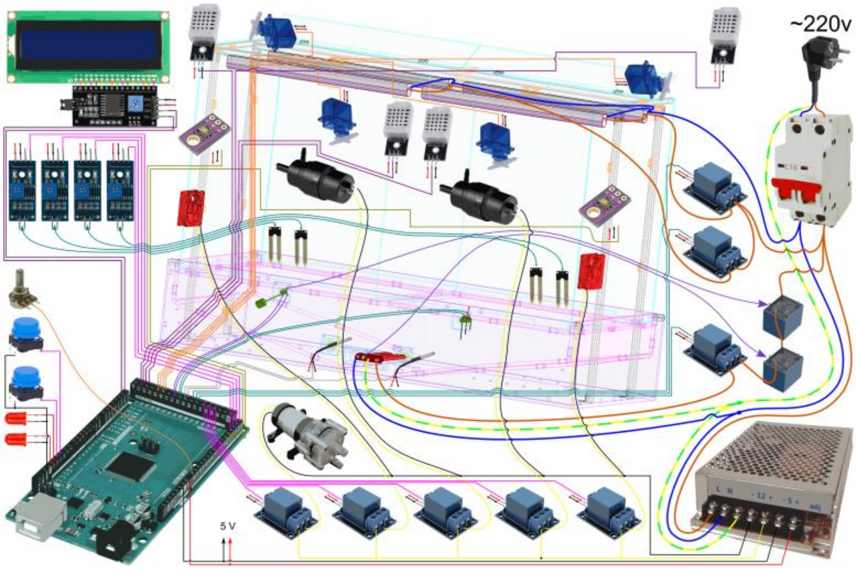

Figure 5. Schematic diagram of the universal table for germination

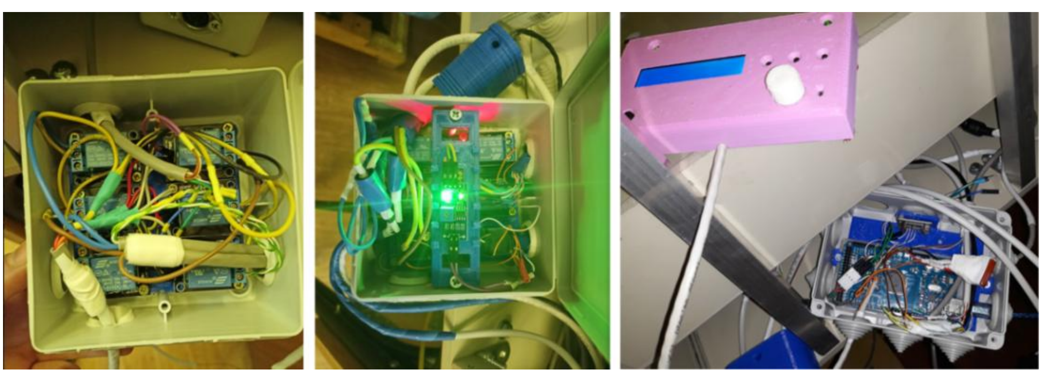

Figure 6. Electrical part of the universal table for germination

In the students' group working on the project, no one had skills in working with microcontrollers, but one participant knew the basics of electrical engineering and knew how to sell. The teachers help students learn the basics of microcontroller technological equipment control. In addition, while working on the project students learned new software, come to understand to work on numerically controlled machines, including a milling machine and a laser cutting machine, and with the help of specialists from the department assembled a table for germination. In the course of work on the project was formalized, the result of intellectual activity – students together with teachers received a patent for an industrial design [25]. The exterior view of the assembled germination table with plexiglass enclosing structures installed is shown in Figure 7. One of the students participating in this project continued his studies in the master's program and now works in the department as a teacher.

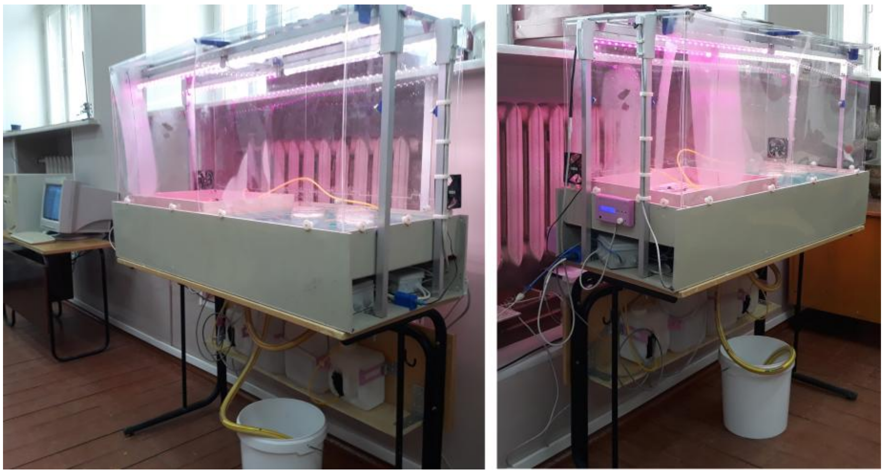

Figure 7. Exterior view of the assembled germination table

4. Discussion

When implementing the student projects was not always possible to strictly follow the intended pedagogical experiment methodology. Sometimes deviations from the methodology were dictated by external circumstances, for example, when according to the terms of the grant the executor must be one student, which made it impossible to officially form students working group. However, these deviations, in the opinion of the authors, are not significant and allow us to consider the results of this pedagogical experiment as successful. It was not possible to implement the use of project results in current educational activities in all projects. This is mainly due to the discrepancy between the specialized disciplines program and the project content. The main use of project results was final qualifying works. After participating in the project, the speakers are well versed in the industry issues, demonstrate fluent command of the studied material and answer questions well.

The projects topics were mainly suggested by the teachers and, if necessary, adjusted to the skills and abilities of students. The students practically did not suggest project topics, and in our opinion, this is one of the serious problems. Due to the small project group’s size, it was not possible to form a full-fledged team with functions division and leaders' selection. Solving individual problems did not cause difficulties if at the planning stage the labor costs and complexity of the task were adequately assessed. A practical problem was communication with the administrative departments of the university; most often this interaction was carried out by the teacher. At the same time, there were no difficulties in interacting with the university personnel providing the use of special equipment – turning, welding work and so on. The actual technical work execution was not difficult, and any work issues that arose were resolved by contacting a teacher or a university engineer.

During the work on the project, the student reports intermediate results several times, writes articles and draws up formulas for patents, which ensures the development of skills in writing scientific texts and allows for better control over the project work progress.

The experience of involving students in the projects showed that students strengthen their theoretical knowledge in the main course of study, expand their horizons, gain practical skills, and acquire interdisciplinary competencies. Most of the students who participated in the project increased their interest in learning. They mastered special disciplines well and successfully defended their work. The experience of participation in the projects allowed students to realize their ideas and go from the idea, through design and construction to the finished product. Students learned how to plan their activities, made need unit's parts purchases, and interacted with university departments and industry representatives. The work of students in small teams allowed students to show their leadership and team qualities. In addition, all students participating in the projects learned to frame their results and defend their projects, defending their point of view. The use of the Arduino hardware platform in the projects allowed students who are not programmers and electronics engineers to get acquainted with microcontroller control, sensors and actuators, and get basic programming and soldering skills.

One of the main project problems was recruiting students in experimental groups. Students are required to have a solid knowledge of the main disciplines, good academic performance, which allows engaging students in additional work, a desire to gain new knowledge, and availability for hand labor. Projects take a long time – a year or two, and during this time, students should not "burn out".

Another task of creating laboratory machines within the student projects framework is the possibility to use the senior students' forces to obtain laboratory equipment [26], which will be used to teach junior students. However, it should be kept in mind that the main aim of the student's project work is to train the student by participating in the project and not to expect that the student's design to be like a commercially developed product. The installations created are not commercial industrial products and do not allow the purchase of new laboratory equipment to be waived. However, such student installations have their own advantages – unlike industrial laboratory equipment, they can be easily repaired and upgraded for new research by the students themselves. In addition, these units inspire undergraduate students to try to create something with their own hands. For example, there are currently plans to upgrade the unit for studying drying processes and to include it in the students' work on educating the drying of hardwood timber. Work is being done to finalize the software part of universal table for germination, but it is successfully used now as laboratory equipment for the second year "Forestry" education field students. And the laboratory unit for the wood cutting processes of study is successfully used as a functioning exhibit for demonstration to students and schoolchildren. Conclusions about the students' attitude to project methods were drawn based on an analysis of their future life trajectory. After completing their bachelor's degree, three people continued their studies at magistracy, one of them is currently studying at the postgraduate school and works as a research teacher at the university.

Despite the overall positive results of the experience, the number of students involved in the projects in relation to the total number of students is not big. However, there is still an opportunity to assess how the experience of participating in such projects affects the student's development, as well as the level of his final qualifying work. The educational standards contain a list of competencies that students must master during their studies. The students who carried out the described projects and their classmates who are not involved in the projects have already completed their bachelor's degree, so the authors have the opportunity to assess how participation in the projects has affected their level of competence. What if we divide the students into two groups: A – experimental group, B – control group of students studying in the same specialty but not involved in project activities. The control group was evaluated only on the performance of the student thesis. The students' work was evaluated based on a comparison according to the parameters given in Table 1.

Table 1. Assessment of students' professional competence formation

Competencies from the educational standard	Evaluation	Measurement unit	Student groups	
			A	Б
1 Is able to carry out social interaction and realize his role in the team	1.1 Completing tasks on time	%	81,4	62,3
	1.2 The meetings frequency of	%	70,3	13,6

Competencies from the educational standard	Evaluation	Measurement unit	Student groups	
			A	Б
	the student team members			
	1.3 Number of participants in student team meetings	%	85,2	0
2 Is able to present the results of the work in a form accessible to the audience and justify their application in professional activities	2.1 Availability of presentations at professional conferences	pieces per person	2,2	0,18
3 Is able to justify the adoption of a specific technical decision in the development of technological processes and products, taking into account the environmental consequences of their use	3.1 Availability of joint articles	pieces per person	3,6	0,14
	3.2 Availability of joint patents	pieces per person	2	0,09
4 Is able to develop technological documentation for the implementation of technological processes	4.1 The proportion of students with student thesis failed the compliance standard check during the initial control	%	40	76,5
5 Is able to independently master the necessary practical skills of using software and hardware	5.1 The presence of a self-produced research activity result in the form of a product on the student thesis defense	%	100	13,6

Systematic and successful activities aimed at attracting students to participate in project activities make it possible to intensify research work at the department. Thanks to the implementation of this initiative, the teacher, acting as the scientific supervisor of the project, gets an additional opportunity to conduct research and select potential research staff from among the students. The university supports students through a system of annual grants. In the period 2008 to 2022, grant support was provided to students under the UMNIK program by the State Fund for the Promotion of Innovation, and grants from the Head of the Republic of Karelia have been awarded since 2022. In addition, students gain skills in preparing grant applications for other scientific and technological competitions.

5. Conclusions

The main limitation of the study was the need for students to combine active work on the project with daily studies. The distortion of the research is that the authors and students working on the project inevitably come closer in their views on approaches to work and study. In table 1, the results of group B include students who did not participate or did not complete their projects. A project chosen by a student with low motivation is usually not completed, but the authors do not consider this a reason to give up the opportunity to give all students a chance for additional development.

To increase the motivation of the student at the initial stage, the student is assigned to conduct a small literature review and formulate his vision of the problem. This material is then used to prepare presentations and abstracts for the student conference. As the experience of the authors has shown, publication in a collection of student papers can be a good motivation for further work. In most cases, the projects have not been commercialized directly, but some of the installations are used as educational equipment. In general, the level of project development can be assessed as the prototype. Almost all of the received installations have published articles in journals, including peer-reviewed ones.

An analysis of students' learning outcomes and their level of mastery of the competencies listed in Table 1 revealed that students participating in projects are significantly more likely to present at conferences, which helps them present their views well and defend them competently before grant and examination committees.

Students participating in projects also have significantly more experience in writing articles and patents, which positively impacts their ability to formulate their thoughts on paper, for example, when writing a thesis. The need to complete grant reports and documents within the established deadlines allows students to participate in projects to master the basics of time management and documentation requirements. As a result of their participation in the project, students can present a real object of their development during their thesis defense; project work takes place against a background of active interaction in the scientific and technical environment, which will help students collaborate effectively in the future workplace.

The authors plan to continue further research by developing a system for monitoring and evaluating student's personal achievements, which will allow them to collect more complete statistics necessary for the formation of an adequate educational system, considering the motivation of the students. The authors also plan to develop a questionnaire for students without IT specialization to study the students' attitude to project activities, including active immersion in IT.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

This work was supported by the Russian Federation Ministry of Science and Higher Education (state research target, theme no. 075-03-2023-128).

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