

The 3DPrint in Technical Education and Creativity Development

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Abstract: - This is a paper whose goal is to analyze exploitation of 3D-print in the technical education and its influence on students creativity. This study is based on analyze of students creative approach to the solution of technical problems. In the industry, the 3D-print is often used for printing new parts of newly developed devices. It is obvious that the 3D-print can be used in schools for preparing parts of students design proposals and their testing. In the past, students of technical schools often creates technical drawings of simple devices and this activities are examples of project based learning. So far, the students only seldom have possibility to realize their proposals otherwise than build it from serially produced elements or kits. This was a significant limitation. Nowadays the 3D-print allows to produce some original parts, whose production would have been impossible earlier. So, the student's work is more like the real work of designers. Many works show that the project based learning has positive effect on student's creativity. Two groups of students were compared in this study: One composed from students working on projects design tasks with use of 3D-print-prototyping and second group in which students used only drawings and CAD programs for solution of their objectives. The students from the first group come up to much better results.

Key-Words: - 3D-printing, Arduino, Prototyping, Project-based learning, Problem-based learning, Programing

1 Introduction

In this is a study is described and analyzed exploitation of 3D-print in the technical education and its effect on student's creativity. This work is devoted to an analysis of students creative approach to the solution of technical problems. Nowadays, the 3D-print technique is often used for printing new mechanical parts of newly developed devices, so called prototyping [1-7]. It's obvious that the 3D print can be used in schools for preparing parts of students pro In the past, students of technical schools often creates blueprints for simple devices and students work on the development of this devices can be considered (from educational point of view) as examples of project based learning [8-15]. Project based learning is most effective and often used approach in technical education. It is often used in the lectures devout to the construction of mechanical assemblies. So far, the students only seldom have possibility to realize their proposals otherwise than build it from serially produced elements or kits. This was a significant limitation of their work. Manufacturing of mechanical parts with original geometry or parts produced by casting, welding or forging was not possible from economic or technological reasons. Nowadays the 3D print

allows to produce some original parts, whose production would have been impossible for students earlier [3,4]. So, the student's work further closer to the real work of designers. The students can used 3D-printer to produce mechanical parts and verify the behavior of assembly on physical model. This approach is very advantageous, because the virtual models based on CAD is sometimes not able to reveal all features of proposed mechanical assembly. It can be said that, the students investigate features of their designs and determine some shortcomings in design. If the shortcomings are identified, the students can propose some alternations of their design. In this way the projected device is improved as well as in the real life. The students have possibility to practice their abilities on different particular problems. These activities can lead to gradually improvements of students skills and development of students creativity. Nowadays many scientific works published in world describe the fact, that the project based learning has positive effect on pupils or students creativity and other mental features. In this work are described the different examples of students tasks and the process of designing. Because the work has often form of collective work, researchers were trying to depict the contribution of different members of working

teams. In the work are discussed also the differences between students approach to the same problems. Two groups of students were compared in this study: One composed from students working on projects design tasks with use of 3D-print-prototyping and second group in which students used only drawings and CAD programs for solution of their objectives [5,6,7]. The students from the first group come up to much better results.

2 Examples of Students Task

The students are working on solution of different problems. In this paragraph we will present you some students works such as: (1) measurement device for calibration of magnetized tape; (2) ejector of cast parts; (3) swaging machine for forging parts; (4) auxiliary instrument for drilling, (5) cooking appliance for slicing and shaping dough, (6) lock a key made by 3D printer [3,4]. Except first task all other tasks require study of influence of the product shape on its functionality. For example, the shape of product influences the size of forces which are needed to pull the forged product out of the mold. Therefore it is very appropriate to use the 3D-print techniques for prototyping. The students work on this practical tasks are very important for development of student skills. When students are working on such projects, the positive effect of such activity is undeniable also in the case if they are not able to find a solution. Experiments realized by students are examples of problem based learning.

2.1 The Construction of Measurement Device for Calibration of Magnetized Tape

In this case students must develop measurement device which is used to verify shape of magnetization curve. The magnetized tape encompasses information in the form of sinusoidal curve which is composed from magnetized cells [18]. This cells are so small, that the magnetic signal can be considered as smooth curve. The magnetic sensor can be used to read amplitude of magnetic signal. The sensor can be controlled by small microcomputer based on Arduino [16,17]. The linear position can be changed by movement of tape or magnetic sensor. The tape movement can be realized by tape dragging on the underlay or the tape is wound on rotating cylinder. Also the position can be easily determined by sensors which are commercially supplied for Arduino-kits. Arduino kits are often used for teaching robotics and automatization. One team proposed the device in which the measurement sensor is drawn over the

tape surface by motion screw. The trapezoidal screw used in this assembly is standard movable screw from the Habelkorn. The position sensor used in this machine was based tachometer for Arduino robots screw. The position of sensor over tape surface was determined easily by known number of screw revolutions and the screw gradient. The second group of students placed magnetic tape on the cylinder whose circuit corresponds to the tape length. The position on of magnetic sensor on the tape was in this case controlled by cylinder rotation and this rotation was measured by the same tachometer as in the previous case. The main problem of this solution was the fact that the tape was not perfectly adjoining to the surface of the cylinder. The cylinder was printed on the 3D-printer and the students were forced to try out different geometry and fitting of this cylinder.

2.2 The Construction of Ejector of Cast Parts

The students have received drawing with the final required geometry of molded part. Students prepared the blueprint of mold with gating system. The students used some software for computer aided preparing to prepared the CAD 3D model of the part. The students at our classes can choose between Solid Works or Autodesk Inventor software. Both this tools allow to prepared 3D-models of parts and molds in format STL (stereolithographical format), which is processable by 3D-printers [2,3,4]. Hereupon the 3D-printer is used for manufacturing model of mold and also model of cast part [19]. This two models are used to verify how tight is cast part in the mold. If the model of cast part is too tightly placed in the mold it is necessary to change the shape of mold. When studying the model, students must be aware of the importance of the slope of the mold walls. Students try to develop optimal shape of mold. Students proceeded in this way: (1) they were trying to determine optimal shape of mold, (2) they used the kits to propose ejection mechanism, (3) the design of control system. First group of students proposed more sophisticated, but also less practical method of ejection. In this case thorn which was used to eject the product from mold was controlled by switch connected to the mold breach. In the second case and the students used simple thorn with spring which force eject the part from the mold. Both teams also proposed the light signalization which signalized if the mold part are closed or not.

2.3 The Construction of Forging Machine

This task was in same way similar to the previous task. Students have received drawing with the final geometry forged part. This model of forging machine will never been able to develop some significant forces, but students can verified on the model concept of real machine [19]. First students prepared the blueprint of product which should be produced by forging. This model was manufactured by 3D-printing. The swags will be also produced by 3D-printing technology. This models will be used to determine the influence swags geometry on the adhesion between the forged part and both parts of swag. It can be said, that students used two or three models to optimize the shape of swag. The 3D-printer is used for manufacturing model of forged product and also model of swags. Both parts of swags are in reality negatives of the final product.

2.4 The Model of the Guide Element for Drilling

The goal of this task is design and manufacture of the model of guide element for drilling machine. Students received from the teacher the blueprint of mechanical part with several holes. In the case of part made from steel or other metal this holes will be made by drilling [19]. These devices were used very often in the industry and allow us to make quickly some holes in the product. These devices are in reality systems composed from flat piece from solid material with holes that are located in places over required hole positions on the product. During the drilling is the borer led through the device. Students will receive the blueprint of specimen and they must to design the device with suitable geometry. The device was prepared by 3D-printing. On this task also worked two different groups of students. In comparison to production of real drilling device is this printed prototype significantly cheaper, which allows to all students to test functionality of their own proposal. Students work on designing this device is composed of these phases: (1) analysis of geometry, (2) choice of drilling tools, (3) design of geometry of the product, (4) testing of functionality.

2.5 The Proposal of the Cooking Robot

In this case students must develop device for slicing and shaping dough or pasta. The students are working on device proposal which allowed to process the dough and formed wafers or biscuit. The first group of students suggested device which is based on rotating cylinder with blades. These rotating cylinder contains boreholes on the surface.

These boreholes are in the shape of biscuit, they are in reality molds for shaping dough. The students ensured the rotation of cylinder by stepper-motor controlled only by switch and electrical resistor. This cylinder was printed on 3D printer and also razor blades used for dough cut were fixed with holders printed with this technology. Low strength of material of the cylinder does allowed work only with a non-sponge dough. The second proposal created by second group of students was represented by the form pressed on the desk by backstage mechanism powered by stepper-motor and controlled by Arduino UNO micro-controller. This solution was much more complicated and also less reliable than previous.

2.6 The Lock a Key made by 3D printer

Last task for students was the proposal of simple combination lock. The combination lock is a type of locking device in which a sequence of symbols, usually numbers, is used to open the lock. The sequence may be entered using a single rotating dial which interacts with several discs. In terms of neat mechanical things to build out of plastics, students proposed figured a single dial sequential combination lock. This device was relatively simple, involve movement, and also show people how a combination lock actually works. This lock like most real combination locks such as a Dudley or master Combination locks, is composed from the core of this lock build from three rotors. Each rotor has a notch in it, and when the three notches line up, some sort of bar can drop into them, and allowing the lock to be opened. The front most rotor is directly coupled to the dial on the front of the lock. All three rotors used in this proposal have tabs sticking out the front and back. Therefore, when the first rotor in the front is turned by one turn, its tab hits the tab on the second or middle rotor. The middle rotor's tab in turn sticks out the back, and with another clockwise turn of the dial catches the tab in the last rotor. Thus, this mechanism worked so that with two turns in the same direction, the back rotor is also engaged. To open the lock, one turns the dial to the right until the notch on the rear most rotor is aligned with the bar. The first number of the combination corresponds to the position that the dial needs to be turned to accomplish this. After the back rotor is lined up, rotation is reversed. By turning counter-clockwise one turn, one will catch the middle rotor with the tab pushing it in the opposite direction. As long as one doesn't turn too far, only the front and middle rotors now turn with the dial. The dial is turned far enough to align the middle rotor. All parts of combination lock except the steel

shaft were printed on the 3D printer from plastics. The technical blueprint of the Lock is shown in the Fig. 1.

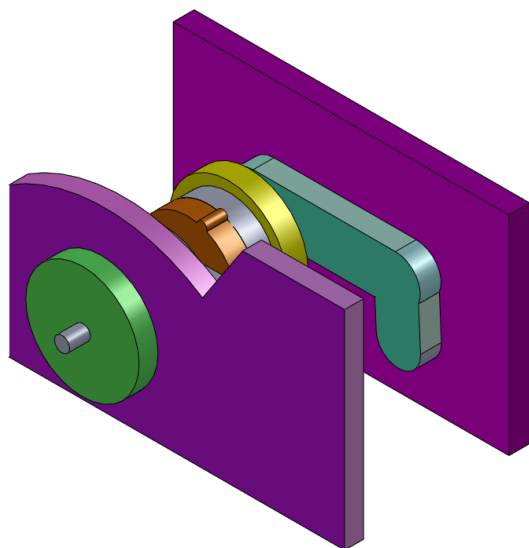


Fig. 1 Combination Lock, 3D model assembly.

3 Educational Theory

3.1 Project and Problem-Based Learning

This two concepts are often interchangeable by many authors, but strictly this two approaches are different. Some authors will notice that the problem-based learning originated in the 1960's and this concept is a teaching pedagogy that is student-centred [8-15]. Students learn about a topic through the solving of problems. In the case of problem-based learning students are often working in groups to solve the problem. The problem often does not no one correct answer. Here we can cite Savery [8]: "it empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem". Contrary to Problem-based learning, the Project-based learning was proposed by John Dewey and William Klipatrick and dates back to beginning of twenties of twenty century. This approach was first used in 1918. Project-based learning is

an instructional approach, where students learn by investigating a complex question, problem or challenge. It promotes active learning, engages students, and allows for higher order thinking. Students explore real-world problems and find answers through the completion of a project. Students also have some control over the project they will be working on, how the project will finish, as well as the end product. If we look at our projects and the way students work we can not directly answer if we used first or second approach in reality we used to some extent both methods. Because students and teacher combined both approaches in their work. The principal difference between this two approaches can be described so: in the case of project-based learning is an approach where the goals are set, on other hand, in the case of project-based learning is that students who complete problem-based learning often share the outcomes and jointly set the learning goals. It is also quite structured in the way that the teaching occurs. Project-based learning is often multidisciplinary and longer, whereas problem based learning is more likely to be a single subject and shorter. Generally, project-based learning follows general steps while problem-based learning provides specific steps. Importantly, project-based learning often involves authentic tasks that solve real-world problems while problem-based learning uses scenarios and cases that are perhaps less related to real life.

3.2 Blended Learning

Nowadays, the utilisation of information and communications technology in education has been an inseparable part of modern education. In the case of the long time work on the students projects is often necessary not only work in the school laboratory but also in the virtual classrooms by applying blended learning. Blended learning enables wide utilisation of psychodidactic theory [20]; this affirms the importance of Rosenberg's TIME category that enables students to work at their own pace and highlights the necessity of creating adapted content material to fit various learning styles [21]. Students often made problems analysis and prepared their technical proposals at home. Students work at their own pace, has special characteristics in the comparison to the learning in the school. The approximate time that is needed for completing

the unit is given, but the pace is up to them. Students are given the study content, which is the cognitive component of their learning process.

4 Results

4.1 Studied Groups

This chapter of our work is devoted to the final analysis. We will compare other results of students of who attended lessons in such organized laboratories with others students. Now, we will describe groups of students who attend this research. These students whose skills are evaluated and analyzed in this work are divided into three different groups:

1. First group is composed from students who have been involved in the project based learning described in this paper. These students solved the tasks described in the paragraph two. Thus, tasks that combine knowledge from programming, mechanics or technology. In this group the students have worked collectively on all partial tasks in project.
2. The second group was also working on the same projects, but the work on the project was partially collective and some objectives were solved individually. For example one student was working on propulsion of small robot and another on its controller.
3. The group of students that not attended these lessons.

4.2 Analysis

The evaluation of the students' results was based on their classification in other subjects, which are closely related to these problems. The results achieved in these lessons have been used for comparison: (1) the base course of mechanics; (2) three consecutive courses of Electrotechnology; (3) and also the course of robotics and programming; (4) course of Mechanical technology. Each evaluation includes a classification from the theoretical and practical part of the subject. The results of the comparison are shown in Table 1. The improvement of students was monitored in set of subjects taught at our school or at associated schools

where students have their own practice as teachers of technical subjects.

The table gives two school grades for each lesson, i.e. a classification from the practical part and from the theoretical part. Next to the average classification grade, we also use the median value in the given group. Both average and median classification are shown in Table 1. In the table are used these abbreviations: AC-average classification and MC-median classification; P-practical part of course and T-theoretical part of course. Comparative groups are numbered in the table in the same order as in the previous paragraph.

Table 1. The results of students in different subjects:

Subject		Group 1		Group 2		Group 3	
		AC	MC	AC	MC	AC	MC
Mechanics I	T	2.3	2.4	2.1	1.9	2.7	2.7
	P	1.2	1.3	1.7	1.5	2.5	2.3
Mechanics II	T	2.8	2.6	1.5	1.5	2.8	2.7
	P	2.7	2.5	1.7	1.6	2.7	2.5
Electro-technology I	T	2.0	1.9	1.1	1.1	2.1	1.7
	P	2.3	2.3	1.0	1.0	2.7	2.2
Electro-technology II	T	1.7	1.6	1.5	1.5	3.1	3.1
	P	1.8	1.8	1.7	1.4	2.9	3.2
Electro-technology III	T	2.5	2.4	2.3	1.8	2.7	2.6
	P	2.1	2.4	1.5	1.5	2.9	2.8
Robotics and programming	T	2.3	2.0	1.7	1.2	2.7	2.4
	P	1.8	1.8	1.2	1.2	2.7	2.3
Mechanical technology	T	1.6	1.4	1.9	1.9	2.0	1.9
	P	2.2	2.2	1.5	1.5	1.9	1.7

The results which are recorded in the Table 1 clearly show fact, that the students, who participated in the Course based on Project based learning have much better results than other. When we will analyze both groups of students who worked on projects we can see, that the students who were forced to divide work equally between one another have better average results than first group. This effect is probably caused by fact, that in the first group some students are not working properly in the

project and they did not take actively part on project. Generally speaking, such a lesson has a very good impact on students.

4 Conclusion

This article was devoted to the problematic of the specific problem project based learning applied on the technical education and the development of technical creativity of the students of technical high schools which are connected to our university. The Technical education is characterized by some specifics and project based learning has key role in it the learning on the technical oriented classes. Students work described in these article used 3D print for preparing technical models of real devices. The students whose take part on the classes have much better results than other students. These results are shown in the Table 1. This table clearly show fact, that the students, who participated in the solution of new problem tasks are better than other students. The creative work of the students has great impact on the students creativity. Because the students work practically on series of "real" technical problems.

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