EDUSCRUM METHOD IN TEACHING STEM SUBJECTS

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Abstract

The article describes the basic principles of the eduScrum method and ways of introducing this active learning scenario into the teaching of STEM subjects at technical universities. Based on work in small teams on small projects this method appears to be one of the most advantageous approaches when teaching basic mathematics courses for engineering students. Two examples of miniPBL materials developed and used in bachelor courses applying eduScrum method are presented, with feedback received from students on this non-traditional learning practice.

Keywords: EduScrum, social skills, STEM education.

1 INTRODUCTION

Active learning methods play a key role in sustainable education, which is one of the Sustainable Development Goals (SDG) announced by the European Union for the next decades. One of the interesting didactic methods that activate students is the eduScrum method. EduScrum is an active collaborative education process that allows students to plan and determine their study activities and their learning process by themselves, supporting responsibility for keeping track of their study progress. While the teacher determines why and what to study, the students determine how to organize and manage it. This is resulting in intrinsic motivation, fun, personal growth and better results. Such personalized learning method has a very important role, as it is positively effecting student's creativity, mutual collaboration, professional communication and critical thinking [1]. The article describes some basic principles of this method as stated in [2] and presents ways of introducing it into the teaching of STEM subjects at technical universities [3]. Various scenarios are available, but individual work or work in small teams appears to be the most advantageous approach when applying the eduScrum method in basic mathematics courses for engineering students.

2 METHODOLOGY

EduScrum method might be introduced in different scenarios. The main idea is that students, individually or as a small team of 4-5 persons, have to solve several sprints during the semester, each covering one specific core topic of the respective subject. Each sprint consists of several problems, starting with easier ones, then next slowly increasing in difficulty, with the last problem being an applied problem related to the respective professional orientation of the student's cohort. The applied problem is a kind of miniPBL approach, where students are asked to work together in a small team and develop a short summary paper, prepare a presentation and present their solution in front of their classmates. Teamwork helps students in need to progress faster in acquiring knowledge, and allows better analysis of the problem and tasks to be solved, as these are deeply thought out, understood and properly solved thanks to discussions among team members. Another advantage of this educational scenario is the opportunity to train and develop social soft skills, such as cooperation, building team spirit, individual responsibility for own contribution to the team's benefit, and the ability to talk about mathematical models when solving applied problems. The fact that students use the acquired mathematical knowledge in solving practical problems of real life is also extremely important.

This innovative approach how to organize teaching process to be better connected to real-life situations was introduced within the Erasmus+ project Pythagoras [4]. The project is primarily aimed at developing policies that will make learning mathematics more inclusive, efficient, enjoyable and real, by intentionally connecting mathematics teaching with real-life cases linked to the students' fields of study. The project addresses the role of mathematics within STEM education and examine how it might be advanced through various approaches: enhancing students' and teachers' digital skills, making mathematics more interactive by introducing gamification, visualizations and interactive animations accessible online, blending teaching and learning by miniPBL approach, automated self-assessment and peer reviews to engage students along learning. Many instructional materials in the form of miniPBL projects were developed as a results of the project, focused on the most urgent environmental issues that have to be

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solved on our planet. In this context, education of mathematics might contribute reasonably to the European Sustainable Development Goals and show the way how to promote sustainable education within the STEM subjects. Presented examples of sprints with miniPBL projects were used within the eduScrum learning scenarios and tested during the project Pythagoras in basic bachelor courses of Mathematics on engineering study programmes.

3 RESULTS

The following 5 topics were chosen to use the eduScrum approach in the course Mathematics I: matrices and determinants, functions with one real variable – domains, graphs, inverse functions, continuity and function limit, local extrema of functions with one real variable, indefinite integrals, definite integrals and their applications. All 5 sprints consisted of 4 traditional tasks commonly required in basic courses that are used to test computational and manipulative skills. The fifth problem was a small project related to some of the professional or environmental tasks. In order to solve this problem it was necessary to compose a suitable mathematical model of the situation, while the solution was leading to usage of mathematical calculations tested in the first four problems of the respective sprint. In this way, a miniPBL approach has been naturally introduced within the eduScrum method, as confirmation of the particular piece of knowledge acquisition, and the ability to apply it in the real context.

One example of the sprint is presented in the Fig. 1. Typical problems related to the topic of definite integrals are included in the first four problems and supplemented by short theoretical questions. Problem 5 deals with the application in mechanical engineering, which was the professional orientation of students solving the sprint. In addition to problem formulation, students are provided also with graphical illustrations and remarks as hints to find the solution, if necessary.

DEFINITE INTEGRALS

Problem1. Calculate area of region bounded by graphs of functions $y=\frac{1}{x}-1, y=\sqrt{x-1}, y=\sqrt{5-x}$ and line with equation $3y=x-5$. Sketch the region and describe it analytically.

THEORY: Write Newton–Leibnitz formula for evaluation of definite integrals.

Problem 2. Calculate area of planar region that is bounded by graphs of the following functions: $f(x)=e^{-2x}, g(x)=e^2,\ h(x)=(e^2-1)x+1$. Sketch the region and describe it analytically.

THEORY: Fill in correctly and sketch the respective graph!

Let function $f(x)$ be even, then $\int_{-a}^{a} f(x)dx = \ldots$

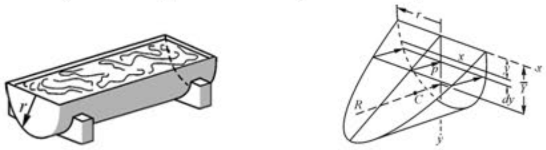
Problem 3. Calculate volume of a solid of revolution, which is generated by revolution of an elementary region EO about coordinate axis x. Region EO is bounded by curves determined by equations $y=e^x, x=0, y=(e-4)x+4$. Sketch region EO and describe it analytically.

THEORY: Explain evaluation of definite integral $\int_a^b f(x)dx$ by means of the substitution method, provided all initial conditions of this method are fulfilled.

Problem 4. Calculate length of curve segment K, which is graph of function $y=\sqrt{x^3}$ on interval $\langle 1, 4\rangle$.

THEORY: What is the geometric meaning of definite integral? Sketch graph for explanation.

Problem 5. Calculate the resultant force R of water that acts on the surface of semi-circular face of cylindrical chute filled with water (see in fig.). Express the resultant in dependence on radius r of semi-circular face of the chute, if the density of fresh water equals to constant ρ.



Remarks:

Resultant force R of water can be calculated as $R=\int_0^r p\,dS$, where $p=\rho\cdot g\cdot y$ is hydrostatic pressure acting in depth y, ρ is the constant density of fresh water, g is the gravitational constant, and $dS=2\sqrt{r^2-y^2}\,dy$ is the area of elementary strip of the cylindrical chute semi-circular face.

THEORY: Let $f(x)$ and $g(x)$ be functions integrable on interval $J=(a,b)$ and let $c,d\in R$ be arbitrary constants. Then: 1. $\int_a^b (c\cdot f(x)+d\cdot g(x))\,dx=$ 2. $\int_a^b \frac{f(x)}{g(x)}dx=$

Figure 1. Example of sprint dealing with topic of definite integrals.

One more applied problem related to the problem of waste accumulation was used in the topic of differential equations, see Fig. 2. Students received a general introduction to the problem in the context of the environmental issues that have to be solved in order to keep sustainable development of the planet. Problem was then posed with necessary mathematical measurements and relations describing the situation, while also some information was included on what mathematical concepts have to be used to generate the mathematical model of this problem and how to solve it properly. The process of solution was distributed to smaller tasks to be solved sequentially until the global view of the environmental problem of waste accumulation could be achieved. The mathematical model revealed also possibilities to reduce the amount of waste and slow down its accumulation at the theoretical level, represented by integration constants in the general solution of the respective mathematical model in the form of differential equation. Students were asked to discuss, what could be the taken measures and ecological restrictions leading to waste reduction related to the constants in the general solution of the mathematical model. Their task was also to investigate how these ecological improvements might influence the form of the respective resulting particular solution evaluating the waste accumulation.

A feedback questionnaire was developed in order to receive students' opinions on these new ways of teaching mathematics closely related to applications in the engineering fields or to the new challenges concerning environment which mankind has to overcome in the near future. Students revealed their feelings openly, while the answers were quite diverse. Some of them found these new methods as very instructive and positively influencing mathematical understanding, while the others found the applied methods as more demanding and distracting. More attention had to be paid to the context and understanding of the application problem itself, than to mathematical calculations and conceptual understanding. Few students also regarded these new methods as contra-productive. This was due to the fact that they were asked to use mathematical knowledge and competencies which they still could not acquire and apply to the professional problem they could not understand properly due to their still not sufficient professional knowledge. The applied problems in the sprints were often not solved at all, or solution was just partially correct. On the other hand, many students enjoyed the way of combining mathematical theory immediately with the applied problems in which it has to be used in order to solve them properly. Their arguments strongly supported such learning and teaching scenarios, because engineering students need to see and understand why mathematics courses are important and they form an essential indispensable part of the curriculum in engineering degree programmes.

Learning Guide for Students

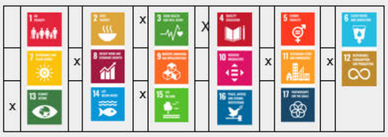
Mini-PBL project	
Student data sheet: Learning Guide	
Title	The waste reduction
SDG attended	Using this UN graphic, we mark such SDG which this project works. 
Content units	Ordinary differential equations of order II with constant coefficients
Sessions	1 sessions of 1h
Hours of work	1h
ICT tools to be used	Available Computer Algebra Systems: Mathematica, Maple, Matlab, GeoGebra, etc.
Context: project statement	The production of waste is increasing with the speed directly proportional to its quantity, due to increasing industrial production and poor environmental measures. To decrease the waste accumulation it is necessary to adopt various ecological measures, as recycling of the produced waste, decrease in the production leading to the decreased speed of its accumulation and decrease of its growth acceleration. These adopted environmental measures cannot lead to the complete diminishing of the accumulated waste on the planet, but they can considerably improve the planet pollution and have beneficial effect on the climate changes.
Tasks and problems	The accumulation of waste is increasing with the speed equal to twice its actual quantity. After adopting strong ecological measures, the speed of the accumulation was decreased to be equal to the actual waste quantity, while acceleration of this growth was decreased to one quarter of the former speed. Consider the amount of the waste to be 1 unit at the time, when the measures were imposed, $t = 0$. The process of waste accumulation can be represented by ordinary differential equation, of order 1 before measures, and order II after the regulations. Already after 2 years there can be visible remarkable improvements and considerable decrease in the accumulated waste. **Task 1:** Assemble both differential equations describing the accumulation of waste before measures and after their imposition.
	Task 2: Find general solutions of both differential equations and their particular solutions determined by Cauchy initial conditions. **Task 3:** Calculate the amount of accumulated waste after 2 years under both circumstances, compare these values, and estimate the impact of the ecological measures. **Task 4:** Calculate the amount of waste after 10 years of functioning measures saving the planet ecology. **Task 5**: Estimate, what would be the necessary measures in order not to increase the amount of accumulated waste on the planet. **Task 6:** Sketch several integral curves of the general solution of ODR II and investigate their forms determined by different values of the included constants c_1, c_2 representing the ecological restrictions. **Task 7:** Comment on the obtained results from a sustainable point of view. Investigate how the values of the constants c_1, c_2 influence the speed of the waste decrease.
Outcomes expected	- Graphics fitting the solution; - Numerical results explained and put in context; - Capture of ICT tools solutions used; - Sequence of steps followed; - Remark computations done by hand and done by ICT tools; - Provide complete answer to questions; - All the results must be presented in the context of the problem;
Guide for learning	- Read carefully the problem statement and the tasks posted. Always maintain a global view of all the projects. - Identify, or try to do a first draft match, the content units of your lecture notes involved in every task. - Take your lecture notes open and review before starting to solve the problems. - Match output expected with the tasks posted, at least as first draft approach. - Follow the order of the tasks, try to increase the knowledge of the problem while you are solving the activities. - Always think that maybe there are different ways to solve a problem. - Use ICT tools to avoid hard computations and check your solutions are correct in different ways if possible. - The solutions are always part of a context, expressing such a final solution totally integrated in the problem posted. - Be sure you answer the complete questions. - Always try to solve the questions by yourself. - If the project can be done in groups, discuss with the groups the proposed problem, to confirm and detect fails or weaknesses, confront strategies, discuss presentation format, etc. Working in groups doesn't mean work less but work better.
Assessment	- Final report; - Oral presentation; - Peer-assessment: students will apply peer-assessment for their periodic performance using online peer assessment tools used and available at the respective institution.

Figure 2. Example of miniPBL problem - student's data sheet with learning guide.

4 CONCLUSIONS

Active learning method eduScrum was successfully applied in teaching basic mathematics course at the bachelor study programmes for engineering students. Subject contents were carefully distributed into 5 separate modules, while students' knowledge acquisition in each of them had been tested on prepared sprints. Each of the sprints consisted of 5 problems. Four of them were traditional and generally used problems supplemented by short related theoretical questions. The fifth problem was applied in the respective field of study of the tested cohort of students. In that case, this problem was a kind of small project students were asked to solve together as a team. Therefore, the eduScrum method has been enriched by another active learning method, namely miniPBL. This method is applied as small project-based learning focused on professionally oriented or environmental issues, in order to bring mathematics close to real-life problems that might be a strong motivation for students to learn it.

Feedback received from students was generally positive, with some exceptions of excellent students, who were asked to work in teams with weekly performing classmates. These conditions were regarded as not quite fair, as well prosperous students felt hindered in their work by the weaker ones, and had no opportunity to get the best award except by doing the work of their weaker colleagues themselves.

Students, in general, find applied problems more difficult and demanding when these are included in tests from mathematics. The reason is quite acceptable. In addition to mathematical calculations itself, when there are many problems and misunderstandings of basic concepts, one must understand the context of the application and problem formulation in terms of the respective professional field. In this situation, there are two separate intellectual activities necessary. Finding solution of an applied problem requires a deep understanding of both, mathematical models and manipulations, and poses practical problems within its respective contexts.

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