Exploring the EduScrum Method's Impact on Mathematics Instruction in Engineering Education

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ABSTRACT

Among a number of well-established active learning activities the eduScrum methodology is introduced as a well-known framework for project management adapted to education of mathematics for engineers. EduScrum is founded on empirical process control theory empiricism, asserting that knowledge comes from experience and making decisions is based on known facts. It was successfully adapted and implemented into the education as eduScrum method. EduScrum employs interactive, incremental approach to optimize achievability of learning goals and control risk. Implementation of this method needs a lot of preparatory work, which means a thorough didactical plan and strategy for the whole period of teaching particular course, and development of didactic materials to be used during collaborative activities in the classroom. Paper brings results on introduction of this innovative active learning and teaching method into basic courses of Mathematics for the first year engineering students. Several resources and tools were used to analyse the results of implemented empirical experiment, as study of research resources, natural didactic experiment, didactic tests and questionnaire that was non-standardised, cognitive and objectively scorable. The aim was to find level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, and as a collective work in small groups. Questionnaire was aimed to discover attitudes and opinions of students on this teaching scenario. Evaluation of experiment results and students' achievements is presented in statistical data supplemented by analysis of feedback obtained from students.

1 INTRODUCTION

The Fourth Industrial Revolution era with emerging 4D industry is imposing new challenges to the whole society and human activities, education at the first place. Universities are requested to provide their students with high scientific and soft-skill competencies needed for their future careers. The roles of teachers in this new framework are changing accordingly. Teachers must be prepared to work within international and multicultural teams practising „group collaboration", rather than work on individual basis, disconnected from everyone else in the world, see [1]. The environmental changes, the lack of natural resources and time, new communication means and media, competitive environment and information data appearing in enormous amounts with high speed, are factors pushing teachers to work differently, to get out of the academic autonomy and isolation, and to collaborate with students and community of colleagues, and consequently to change the traditional ways of delivering knowledge, as mentioned in [2].

Giving our students a stimulating learning experience in various different learning environments and introducing innovative ways of teaching focused on active learning is at the heart of the Education Strategy of our age, [11]. Then main goal of this strategy is to enhance the quality of teaching and assessment, by working with students to draw on expertise and best practice both within and outside the institution, developing thus also teaching staff at all levels, and offering both - teachers and students, a vibrant and transformative experience. We should work with our students as partners, to enable them to develop their ambitions, fulfil their potential and make a positive contribution to the world, [3].

2 ACTIVE LEARNING METHODS

Many various experiments have been realised to study benefits of active learning and various analyses were published in a plethora of studies. We can mention some of the most important ones: an increase of content knowledge, development of critical thinking and problem-solving abilities, creative thinking, imagination, openness, collaborative and interpersonal skills, responsibility, and many others. Learner motivation, definitely, remains the most important from all the benefits provided by implementation of active learning methods, see [4] - [6].

Among a number of well-established active learning activities the eduScrum method will be introduced in details. Scrum methodology is a well-known framework for project management, and eduScrum is its adaptation to education. EduScrum, like Scrum, is founded on empirical process control theory – empiricism. Empiricism asserts that knowledge comes from experience and making decisions based on what is known. EduScrum employs an iterative, incremental approach to optimize the achievability of learning goals and control risk. Implementation of this method needs a lot of preparatory work. This consequently means to prepare in advance a thorough didactical plan and strategy for the whole period of teaching particular course by this method, and careful development of suitable didactic (teaching and learning) materials that are to be used during the collaborative activities in the classrooms, in more details described in [7] and [8].

The main idea is to prepare a detailed timetable of many specific activities distributed throughout the course run, during which students cooperate in small groups, usually 4 – 5 persons, and solve as a team in advance prepared collection of problems that are related to particular educational material unit, called sprint. Number of problems to solve might vary, but usually there is one problem attached to each team member. Teams of students work independently, in terms of their own organization and distribution of work in a given time slot. They can discuss all issues together and solve given problems individually or as a team, which is managed by one of them who acts as a group leader – scrum master. This role circulates among all students in the group during the course. Group leader distributes task problems to members of his team, and she/he is responsible to check and correct their solutions, to collect them all and finally she/he reports on the achieved results of the particular team work. Finally, students discuss the whole activity with all other groups in the class.

3 EXPERIMENT WITH EDUSCRUM METHOD IN TEACHING ENGINEERING MATHEMATICS

European project DrIVE MATH – Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, No. 2017-1-PT01-KA203-035866, developed and managed by the ISEP University in Porto, Portugal, is aimed at developing a novel and integrated framework to teach maths classes in engineering courses at the university level. Project partners, Technical University in Chemnitz, Germany, University Lyon 1, Claude Bernard in France, and Slovak University of Technology in Bratislava, Slovakia, cooperate on examination of the best strategies for implementation of active learning methods, innovative teaching strategies and adaptation of course curricula emphasizing the problem-based-learning approach, learning by doing (hands-on), and application of the eduScrum as pedagogical approach promoting active learning in engineering mathematics courses. More information is available at the project web-pages [9] and [10].

A short analysis of the results of experiment carried out at the Faculty of Mechanical Engineering STU within the DrIVE MATH project activities is presented in the following. Experiment was implemented in the academic year 2018/19, in the basic courses Mathematics I and Mathematics II of bachelor study programmes for the first year engineering students. The randomly chosen group of 99 students attended together lectures from mathematics delivered in lecture theatre, where the respective theoretical parts of maths were presented with example solutions of selected problems and various dynamic applications on PC. Students were distributed to 5 smaller working groups, about 20 students in each, for attending tutorials, while various teaching scenarios were applied during the academic year: team work, individual work, revision of theory, or simple presentation of solution strategies and examples of solved problems by teacher.

EduScrum method was implemented for the team work of students in small groups. There were prepared and implemented 5 sprints for team work in the first semester for subject Mathematics I, and 3 sprints for team work in the second semester for subject Mathematics II. Students were distributed to small groups of maximum 5 persons, randomly and according to their own choice (sometimes there were only 3 or 4 of them in one group), and they could use all available resources (open books approach) to find the solutions, together or one by each, according to their decision.

For comparison, there was applied also an alternative method of individual work, which was realised by elaborating worksheets prepared for students as tests with simple tasks. Students had to solve these test individually as closed book tests, usually after a self-study period, and they had to write 4 tests in the first semester and 3 tests in the second semester.

The main goals of the experiment were to find out:

- abilities of students to solve mathematical problems independently, and within a small stable group throughout the semester,
- attitudes and opinion of students on this form of teaching scenario,
- opinion of students on different teaching and testing styles – team work by means of eduScrum and individual work by writing tests.

Topics of sprints in Mathematics I covered Linear algebra, Functions with one real variable – basic properties, Differential calculus, Integral calculus I – indefinite integrals, and Integral calculus II – definite integrals. In Mathematics II the covered topics were Coordinate geometry of Euclidean space, Extrema of functions with two variables and Multiple integrals.

Each sprint consisted of 5 problems related to particular topics, one or two of which were settled as applied problems from the mechanical engineering field. Students were supposed to work in small teams in groups of 5, while always another one of them was the scrum master in the role of team leader. During the team work students cooperated together, though each one was responsible for solution of one from the problems distributed by team leader. They were allowed to use all study materials prepared by themselves. Major part, about 60 minutes of the practical exercise lasting 100 minutes, was spent solving the tasks. Team leader collected team results and delivered these to teacher before the presentation part started. Each group had to present one of the problems in front of the class, while team leader was supposed to do so. Finally, after checking of delivered solutions, teacher attached the points to each of the group so that all students in the group received the same total score of this collaborative work.

Individual work during classes consisted of self-study at home and consecutive individual work with worksheets prepared for students with problems to be solved without using any materials. Here the problems consisted of simple and more mechanical exercises, while 4 chosen topics for Mathematics I were Limits of functions and equations of asymptotes to function graphs, Derivatives of functions, Integration methods for indefinite integrals, and Determination of integration domains for definite integrals. In test for Mathematics II topics included Differential equations, Partial derivatives of functions with two variables and Integration domains for multiple integrals. Each student reached individually his point score which was added to the score he achieved from the team work.

Several resources and tools were used to reach the results of the empirical experiment, such as study of research resources, natural didactic experiment, didactic test and questionnaire. Used didactic test was non-standardised, cognitive and objectively scorable. This simply means that we have invented our own questions, focused on feedback we expected to receive from students, which was their opinion on different forms of educational strategies and scenarios, and assessment of study achievements. Questionnaire was aimed to discover attitudes and opinions of students on this teaching scenario and on inclusion of application of mathematics to the subject itself. Cognitive tests (surveys, pilot tests, and other tools) can be used to understand how respondents interpret your questions and instructions, understand the meaning of survey questions, and to recognise not well formulated questions. This type of testing can also evaluate different survey techniques used in the field to increase response or cooperation, and can help to sort out the meaning of survey responses. The aim was to find out the level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, and as a collective work in the small groups. Test was objectively scorable, as the items in it left no room for judgment in the scoring of responses. The most common form of objective item is the multiple-choice cognitive item, which eliminates the examiner bias and errors.

Respondents' opinion on the implemented eduScrum method for the team work compared with the individual work was obtained also by free interviews with students.

4 ANALYSIS OF EXPERIMENT RESULTS

Prior to qualitative analysis of experiment results the analysis of its respondents is presented. The experiment was attended by 99 students, from whom

- only 1/7 were female students,
- almost 50 % were grammar schools graduates,
- more than 30 % graduated from technical secondary schools with mechanical specialisation,
- almost 20% graduated from other secondary schools,
- almost half of students have reached Matura from mathematics,
- many of students attended 5 and more lessons from mathematics per week at the secondary school, due to their choice to attend seminar from mathematics aimed to prepare students to Matura from mathematics and to take some topics at the university level (differentiation and integration of functions).
- number of students, whose mark from mathematics at the secondary school was 1 or 2 or 3, can be regarded as comparable, which was reflected in the overall average mark from mathematics at the secondary school that is very good – 2,2 (median is 2). This average mark was influenced only insignificantly by number of students (8 %) who received weak mark 4 from mathematics.

Further on it was found that almost one half of students attended Preparatory course of Mathematics at the faculty, which is realised each academic year before the start of the winter semester. Course is aimed to students who need to supplement and strengthen their knowledge from secondary school mathematics. As much as 63% students from those, whose mark from mathematics at the secondary school was 4, also took this course. It follows from the above that students from secondary schools have got very good ”initial conditions“ for the start of their engineering university study. It was assumed that the better mark from mathematics at the secondary school means the better score achievement in the experiment.

The experiment was still going on when this paper has been written (it was approximately in the second third of its run) the overall statistical verification will be realised after its completion, i.e. at the end of the second semester of the academic year 2018/19, in June 2019. Some of the partial results are presented in this paper.

Average point score for team and individual work was over 60%. In team work, this score was influenced by a very small, almost zero number of points students achieved for solving applied mathematical problem in each topic. Score in individual work was influenced by problems caused by insufficient knowledge form the secondary school mathematics, comparison see in Fig. 1.

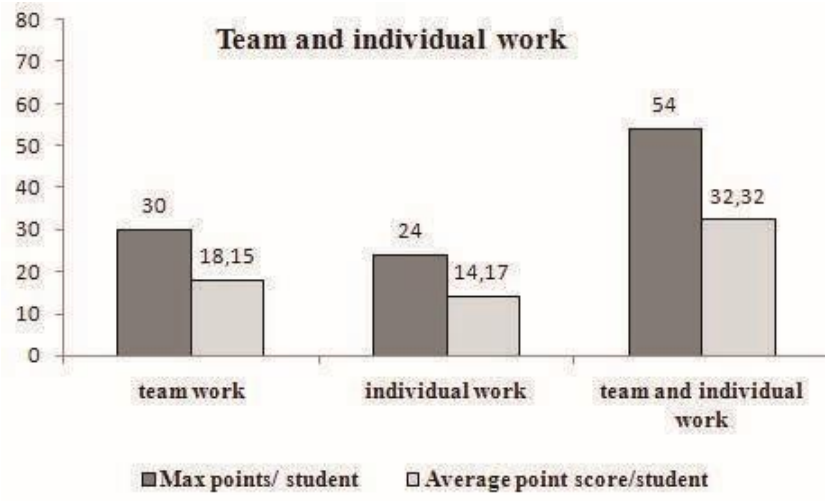

Fig. 1. Results of team and individual work

More than half of interviewed students (52,6%) regard mathematics as demanding subject (“very demanding” and “demanding”), while mathematics is not demanding only for 5,2 % of students. One of the rather negative aspects is the fact that after almost 2 semesters of study at the university, many students still evaluate their knowledge and skills from secondary school mathematics as weak, see Fig. 2.

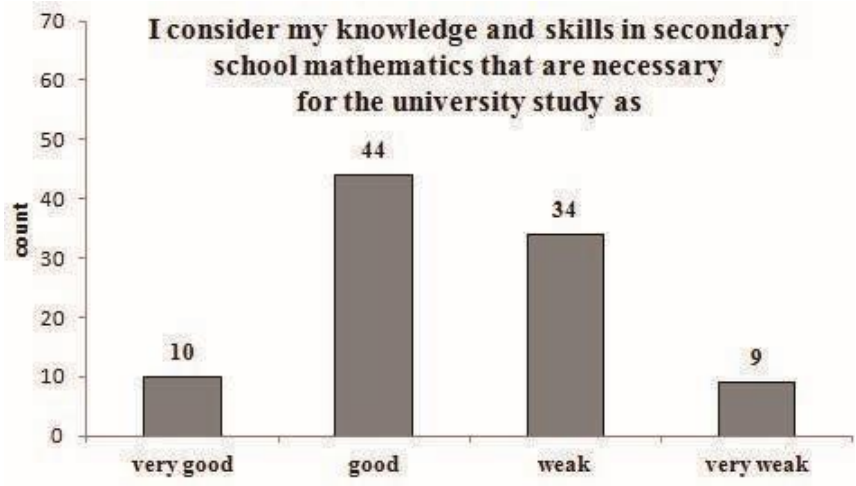

Fig. 2. Self-assessment of the secondary school mathematics knowledge

These facts could be particularly explained by the following arguments:

- students came to study at FME STU from different types of secondary schools with different approach adopted to teaching mathematics and different scope of the subject, which was reflected in different levels of their mathematical knowledge and skills,
- students do not have sufficient working methods, habits and skills for study at the university (to work independently, systematically, to be able to apply knowledge in practical tasks, to acquire knowledge, which is steady and sustainable, ...),

- university freshmen in the 1st year must overcome the difficulties of the transition period changing their study approach adopted at the secondary school to the university style,
- students who attended Preparatory course of Mathematics were „directed“ to take it by their parents, or these students were the best ones, who expected to receive more information there, not only to repeat the knowledge they have already acquired.

Majority of students appreciated team work assessment as prior to individual work (almost one half), and the next big group did not prefer any of them, as they found the applied teaching/assessment strategy as having little effect or influence on their study achievements, see Fig. 3. It could be interesting to know, which students, the better ones or not, made the choice of answer “team work prior to individual work”.

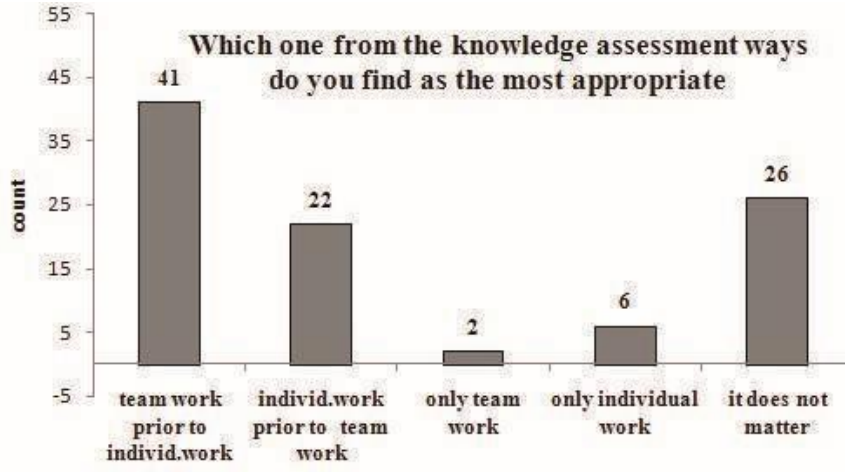

Fig. 3. Comparison of team and individual work

As mentioned before, average score in team work was influenced by applications of mathematics included in each from the topics. These problems caused difficulties to 75% of students who answered that it was “very difficult” and “difficult”, see Fig. 4.

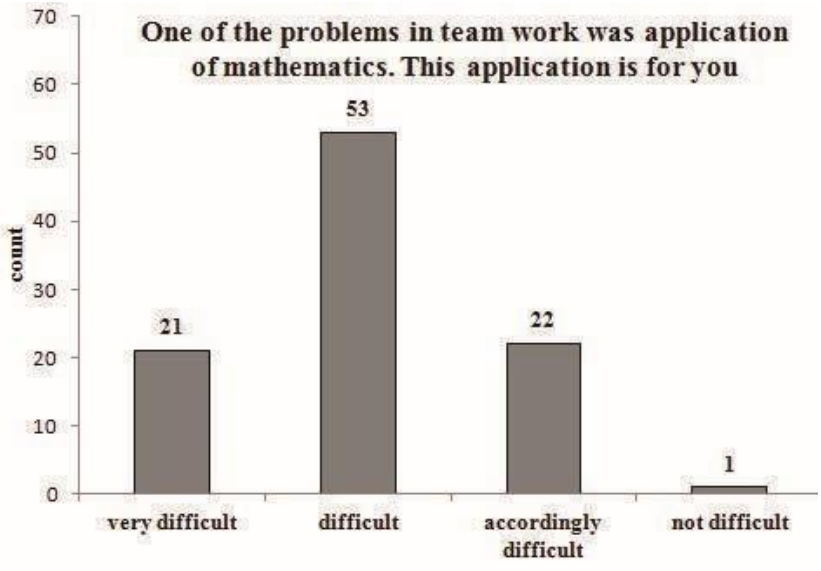

Fig. 4. Complexity of applied problems in subject mathematics

Interviews with students revealed also that:

- applications of mathematics demonstrate how mathematics can be used continually in special technical subjects,
- these problems need to be introduced into teaching mathematics from the first year of university study,
- students "started" to work with different variables (in mathematics variables are denoted usually only as *x*, *y*), and also with constants denoted generally (e.g. gravitational acceleration constant *g* usually understood as value 9,81 m/s^2),
- students became aware of the parallels in the conceptual backgrounds of mathematics and technical subjects, for instance mathematical concept of stationary points of function is related to concept of the equilibrium position of the state in technical disciplines.

Remark: Used applications of mathematics were selected from the lecture notes for specialised subjects taught at the faculty. Some of them are introduced in the lecture notes as examples of solved problems. The advantage of these applications is that once in the further study students will "remember them".

Questionnaire survey revealed, see Fig. 5, that team work helped more than to 72% of students to understand learned content better. As they said in the interview – this taught them also to work in team, to be responsible for their solutions and for the team as a whole, to lead constructive discussions about problems, and to gain new knowledge in problem solving. Individual work did not only help to 1/7 of students to practise learned material better, but up to 85% of students grasped the learned topics considerably better than they expected at the beginning of the academic year.

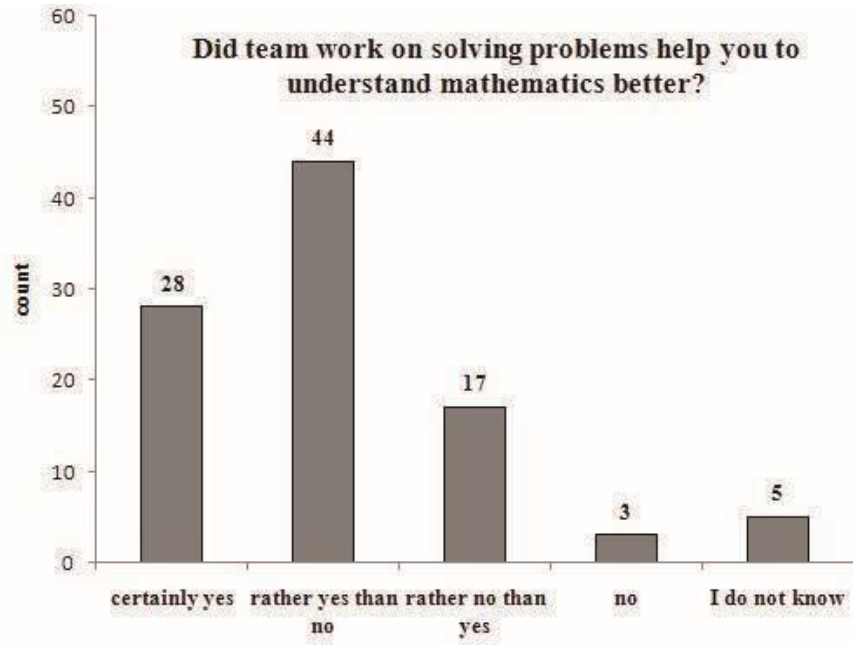

Fig. 5. Team work on solving mathematical problems

Traditional ways of assessing knowledge of students at the secondary schools, and also at universities (up to now), are based on individual work of students in form of written tests. EduScrum method introduced to students a new way of knowledge assessment, which they rated positively. Interview results and questionnaire showed that up to 80% of students would prefer to assess knowledge in mathematics during semester not only by individual or team work, but in combination of both methods, as can be seen from diagrams in Fig. 6. The newly implemented eduScrum method, chosen as the most recommended way of teaching/learning and assessment scenario, proved to be interesting not only for students, but for teachers, too.

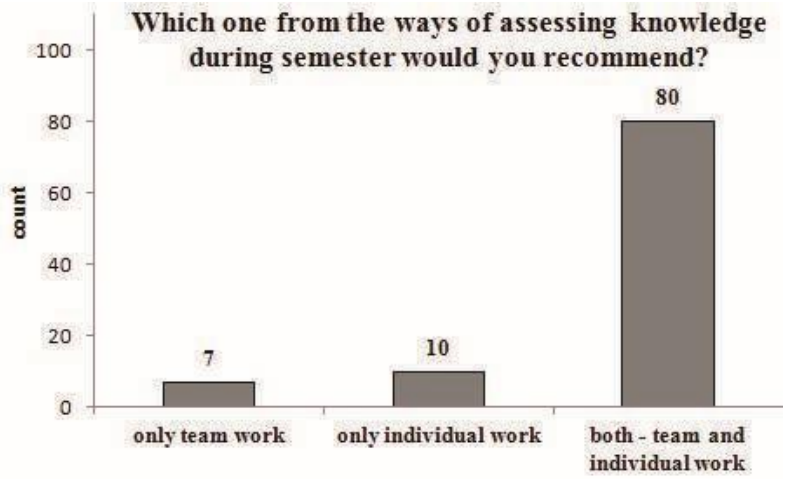

Fig. 6. Preferred ways of assessing knowledge during semester

5 SUMMARY AND ACKNOWLEDGMENTS

The main goal of the described didactical experiment was to understand priorities of young people who begin as freshmen at the technical university studies with diverse study strategies, very different level of knowledge and learning skills, and uncertain motivation. University educators seek to improve their teaching methods in order to meet the expectations of newcomers, but sometimes our efforts are directed in wrong way, missing the target group of students. Their needs differ from our conviction how they are used to work, learn and acquire new knowledge and information, due to many factors that influence our everyday life and inevitable generation change.

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