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Implementation of Agile Methodologies in an Engineering Course

Jana Pócsová *, Dagmar Bednárová, Gabriela Bogdanovská and Andrea Mojžišová

Institute of Control and Informatization of Production Processes, Technical University of Košice, Němcovej 3, 042 00 Košice, Slovakia; dagmar.bednarova@tuke.sk (D.B.); gabriela.bogdanovska@tuke.sk (G.B.); andrea.mojzisova@tuke.sk (A.M.)

* Correspondence: jana.pocsova@tuke.sk; Tel.: +421-55-602-5196

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Abstract: At present, a new generation of students is studying at universities with their specific abilities and skills. In addition to hard skills, potential employers also require significantly developed soft skills from their employees. The school, and not just the university, is entering this process in a different position than in the past due to the changing requirements placed on it. Activities in the school environment must adapt to emerging trends. This article explains how present-day requirements on graduates and specifics of the new generation of students challenge the approach to education. In order to increase the efficiency and attractiveness of the educational process, the SCRUM framework has been implemented into course Mathematics 1. The re-designed course was implemented and validated by an experimental group of students in the academic year 2019/2020. Two questionnaire analyses and a comparison of learning outcomes were conducted to find out the answers to research questions. The results of students indicate that agile methodologies are useful for increasing the efficiency of the educational process. The paper offers our proposal for the introduction of agile methodology into the educational process and our first-hand experience with this way of teaching and its impact on the studying results of the experimental group and, last but not least, suggestions for possible improvements.

Keywords: agile methodologies; education; mathematics course; soft and hard skills; SCRUM

1. Introduction

A new generation of students (so-called Generation Z—people born from 1995 to 2010; according to some sources, between 1997 and 2012) is currently starting to study at universities. They, compared to the previous generation, have a higher level of knowledge, skills and abilities in using information and communication technologies (ICT), but, on the contrary, a lower level of analytical skills. According to Marcie Merriman [1], the Z generation excels in its ICT skills, in the speed and efficiency of information retrieval, but on the other hand, they do not have the ability to systematize, critically evaluate and use this information. Another significant ability of the Z generation is the creation of contacts, immediate communication, exchange of information and skills—in other words, their complete internal readiness for teamwork and the development of the so-called soft skills. These properties are necessary for better application in the current industrial and social conditions. These aspects and assumptions of this generation of students must be taken into account when planning and improving the educational process in order to increase the quality of acquired knowledge, skills and abilities.

In education, two important components are students' abilities and internship needs. According to the World Economic Forum report [2] traditional school education does not develop the skills necessary for practice [3,4].

At present, demand outweighs the supply of jobs. Nevertheless, employers, and not only in the IT sector, describe problems with filling these positions with qualified people, precisely because of their low level of soft skills. Therefore, in addition to the content, modern 21st century education at universities should lay particular emphasis on the development of digital literacy, the use of information technology, the ability to solve practical situations by quantitative expression, plan activities, develop communication, personnel and interpersonal skills, solve problem situations, compile and manage work teams, make decisions, create and to manage good working relationships, think critically and analytically and, last but not least, to be able to negotiate and persuade.

In order for graduates to find employment and be able to grow professionally, it is necessary to change the traditional method of education. It is desirable to incorporate the development of social and emotional learning (SEL) into the educational process.

SEL can be divided into character qualities (curiosity, initiative, persistence/grit passion plus perseverance, adaptability, leadership, social and cultural awareness) and competencies (critical thinking/problem solving, creativity, communication skills, collaboration).

According to research carried out over a period of 20 years, the 10 most important skills needed for practical application are depicted in Figure 1 [5].

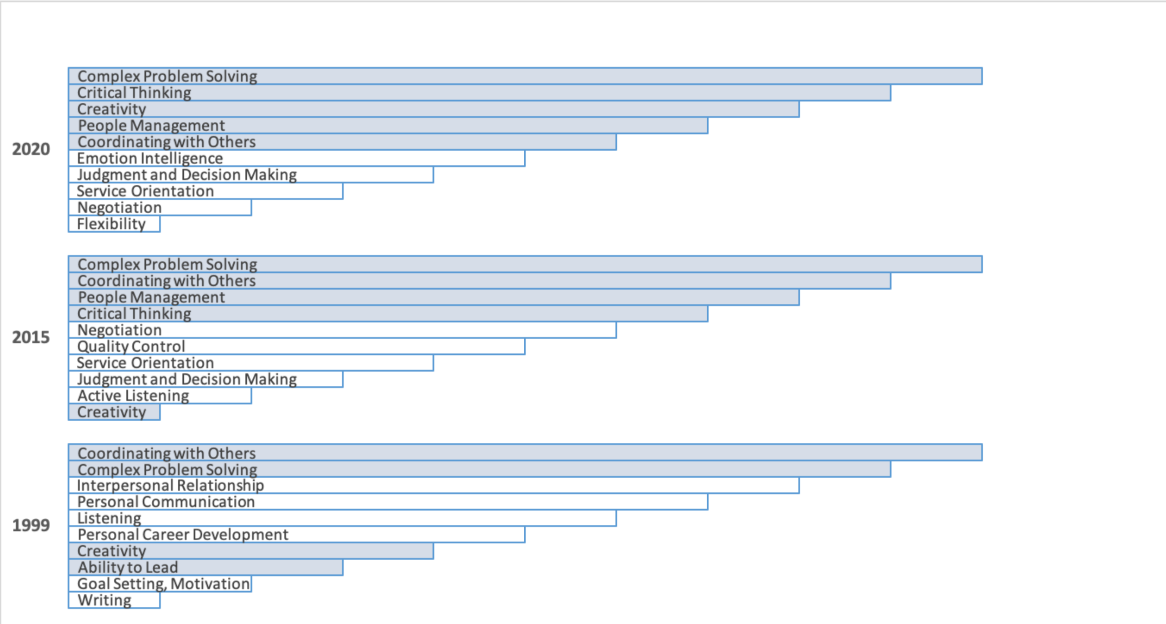


Figure 1. Development of employers' preferences for employees.

Research published in [6,7] has shown that soft skills are as important as hard skills for the successful integration of graduates into industrial practice.

For these reasons, teachers implement various new didactic techniques, approaches and methods in education from other areas. In recent years, one of the approaches implemented into education is Agile Development or Agile (the approach, known from project management).

1.1. Agile

Agile Development is a set of methods, frameworks and practices which focus on evolving solutions iteratively through small increments done by self-organizing, cross-functional teams [8,9]. It is based on the values and twelve principles proposed by a group of software practitioners in 2001 in the Manifesto for Agile Software Development [8,9]:

Individuals and interactions over processes and tools
Working software over comprehensive documentation

Customer collaboration over contract negotiation
Responding to change over following a plan

Agile Development is an iterative team-based approach which favors team communication and interaction. Agile means dynamic, fast, interactive, iterative, responding quickly to changes, etc. [10] Agile methods have become popular with a wide range of organizations, such as Amazon, Google, Adobe, Oracle, Microsoft, Facebook, Adobe, Siemens, BBC, CNN, etc.

There are quite a few Agile methodologies including SCRUM, Kanban, Lean programming, eXtreme Programming (XP), but the most widely used is SCRUM [11].

SCRUM is an agile framework of project management that originated in the early 1990's and was created by Ken Schwaber and Jeff Sutherland [12]. Its name comes from the term scrummage (abbreviated scrum) in rugby, where "a group of attacking players from each team who come together with their heads down and arms joined, and push against each other, trying to take control of the ball" [13]. It is a method for restarting play. This word represents an efficient team with a clear goal. The SCRUM defines roles, artifacts and ceremonies (Figure 2) [12].

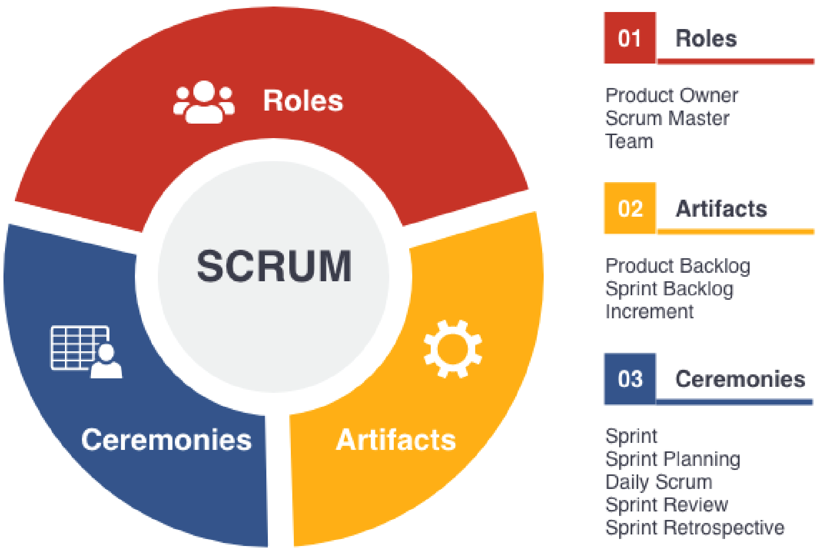


Figure 2. SCRUM.

SCRUM has the following roles [9,10,12,14]:

- Product Owner—is responsible for the project/product vision and transparent communication with the team, customers and society. Product Owner defines priorities, determines what the final value of the product should be and strives for the best possible results. Their goal is to have a successful product.
- SCRUM Master—helps the team to achieve the goals of the project. SCRUM Master is responsible for ensuring that the team has a productive work environment, that they live by agile values and principles and comply with SCRUM processes, procedures, and methods.
- Development team—is responsible for delivering a potentially marketable product at the end of each sprint in the sense of Definition of Done. The team organizes its activities itself and therefore it is up to its members to turn the user's requirements into a functional product. The advantage is that team members have different knowledge and skills that they can use. Responsibility for the final product lies with the team as a whole, regardless of which member participated in the implementation of individual parts.

SCRUM defines three artifacts [9,10,12,14]:

- Product Backlog—is an ordered list of the prioritized items which are necessary for achieving the product's (project's) aim.
- Sprint Backlog—is a list of items from Product Backlog selected for next Sprint.
- Increment—are all items from Product Backlog completed during a Sprint.

In SCRUM are prescribed next ceremonies [9,10,12,14]:

- Sprint—is a basic part of SCRUM. Sprint is a fixed timebox (usually 1 month or less), during which the team has to achieve the Sprint goal.
- Sprint Planning—during Sprint Planning, items for Sprint Backlog are planned.
- Daily Scrum—is a short Development Team gathering where each member shares information about what they worked on the day before, what they plan to work on that day, and whether they have any problems or blockers the rest of the team should know about.
- Sprint Review—during Sprint Review is Increment is inspected.
- Sprint Retrospective—is an effective tool for getting feedback and creating a plan of improvements for the next Sprint.

In practice, Agile has become the new mainstream in recent years [11,15]. The 14th annual State of Agile survey saw [11]: "95% of respondents report their organizations practice Agile development methods" and "Scrum (58%) and related variants (18%) continue to be the most common Agile methodologies used by respondents' organizations". This trend had a corresponding response in the teaching of computer science and software engineering, where agile methodologies became an integral part of it [16–18].

Initially, Agile was mainly about teaching the individual methodologies, such as SCRUM and XP [15,18–20]. The actual teaching of methodologies is currently carried out through various approaches, as only; a theoretical presentation of individual methodologies in the form of lectures is not sufficient [21,22]. These lectures are complemented by practical exercises or workshops [15,23], implementation of various games [16,19,24] and educational applications [16,25]. Examples of game implementation is the game SCRUMIA, which focuses on teaching SCRUM in computing courses [19] and especially on understanding its concept and its application in specific situations. Furthermore, various LEGO games/simulations are popular, primarily for teaching SCRUM [24,26]. In his review of the literature, Mahnic [22] pointed out that practical experience is crucial in teaching SCRUM and that the use of simulation games is one of the solutions.

Gradually, agile methodologies have begun to be used as an integral part of the computer science educational process for support of student teamwork [16–18,22,23,27,28]. Students gain practical experience with agile methodologies, teamwork and cooperation with "customers", which prepares them for practice and improves their job prospects, as employers also prefer graduates with these skills. There are also examples of using agile for teaching and projects in Computer education in secondary schools [29,30].

In an effort to change and modernize teaching, the use of agile methodologies is increasingly expanding into the teaching of other subjects at all levels of education. In various aspects, the agile approach to software development has a lot in common with the educational process, whether it is diverse teams, fixed time units, detailed planning, constant assessment or feedback control. Lang proposed [31]: "The term agile learning to refer to the application of the processes and principles of agile software development to the context of learning".

Based on the Manifesto for Agile Software Development, its education-oriented counterparts were created. Among the best known is the "Agile Manifesto in Education" by Kamat et al. (2012) [32] and the "Agile Schools Manifesto", presented in 2011 by Peha [33]. Both of these manifestos were created on the basis of the Manifesto for Agile Software Development, however they contain various modifications in the context of education. While Kamat et al. focus on values in education, Peha argues that schools should be run in agile way [32,33].

The implementation of agile methods in education is also varies. Alfonso and Botía implement into the education process their own "a particular iterative and agile process model that serves both as a pedagogical tool for the teacher, and as a subject matter for students" [34]. Andersson and Bendix described the eXtreme teaching framework based on XP [35].

However, the SCRUM framework is most often implemented in education. It is most often associated with active learning, cooperative and collaborative learning, flipped learning and gamified learning. Duvall et al. define and implement the Scrumage (SCRUM for Agile Education) method into the teaching of Discrete Math [36]. The method is based on SCRUM and implements several pedagogical approaches (lecture, flipped learning, gamifield, etc.). Another application is eduScrum [37], which implements its own framework built on SCRUM into the classroom environment. Their guide presents role, events, artefacts and rules [37]. Vogelzang, et al. implement SCRUM into context-based Secondary Chemistry Education [38].

In the field of education, various agile techniques are implemented using different approaches, but the most used ones, which are marked as suitable for education, are daily scrum, pair programming (XP) [30,34,39], Kanban board [40] and Test Driven Development (TDD) [18]. The various deployments of Agile in education are mainly used by SCRUM [20,23,25,27], eXtreme Programming [18,20,23,30,39], Lean [23] and Kanban [23].

Several of these sources report a positive effect of agile methods on education [27,41]. Cooperation between students leads to "higher interest, higher retention, and higher academic performance" [38,42].

1.2. Agile Methodologies—Practice versus School

Agile methodologies of project management are typical for many IT companies. By implementing them in the educational process, students will acquire, in addition to the necessary knowledge (of the course), also certain abilities, skills and especially experience with this type of management. This will subsequently improve the student's transition from school to practice.

When implementing an agile framework in the educational process, it is necessary to be aware of the differences between practice and school. In practice, each member of the team has the necessary knowledge, skills and abilities for their activities. Based on them, he/she is accepted into a specific team. In the school environment, the student acquires knowledge and skills. This fact fundamentally influences the actual implementation of the pillars of agile management in the educational process and defines other differences.

In practice, the team is evaluated as a whole and also, as a whole, is responsible for the final product. In the school environment, it is necessary to evaluate the work of the team, the work of a particular individual within the team, but also the progress of the team and its individuals with regard to meeting the set educational goals and requirements. In the school environment, this assessment takes place throughout the educational process as an integral part of it.

In practice, it is possible to slightly or fundamentally adjust the time (if the customer agrees), which is reserved for solving partial tasks and problems. In the school environment, time is strictly limited, and it is not possible to adjust the education part of the semester often either in terms of the scope or content of the curriculum. It is possible to slightly adjust the time allowance for individual units, especially if it is a course from the mandatory composition of courses.

1.3. Reasons for Introducing Agile Methodologies into Educational Process

With regard to the above-described practice requirements for university graduates, the characteristics of the Z generation and the conditions imposed on the educational process at technical universities, we have summarized the reasons for changing the way of managing the educational process in the following points:

- Increasing the efficiency and attractiveness of the educational process itself.

- Development of communication competencies of students on a professional topic.
- Development of soft skills of students.
- Increasing student activity during face to face education.
- Efforts to involve all students in solving tasks and problems.
- Reducing the number of failed students who gave up their studies during the semester.

When implementing agile methodologies into the educational process, the division of students into teams, the work of the team inside and the subsequent communication of the team towards the teacher and individual team members with each other play an essential role. During standard lessons, only the same individualities of students are actively involved in the educational process. The reasons are different. It is often a lack of knowledge, an inability to express ideas using professional terminology, or other interpersonal characteristics (temperament, personality type, etc.). This problem is eliminated when communicating with peers. Subsequently, the group as a whole can solve even more complex tasks and problems.

Another reason from the teacher's point of view is that the division of students into individual teams will allow the teacher to use a more effective way of managing the education unit, as follows: if 30 students are present at the class, they will be divided into six teams of five students and solve individual assigned problems within the team and the unanswered problems will be reduced from 30 (number of students) to a maximum of 6 (number of teams), because when students interact in teams a number of problems will be solved or described by only one common denominator, which will make the whole educational process more efficient and fast.

From the students' point of view, the introduction of agile methodologies into the educational process represents an opportunity to develop the above soft skills, such as teamwork, development of communication skills, time management, comprehensive problem solving and more.

1.4. Selection of Course for Implementation of Agile Methodologies

From the analysis of available resources, it is clear that agile methodologies have already been successfully implemented, mainly in courses related to programming and information technology. In this approach, we decided to implement these principles into a completely different type of course. We chose the compulsory, general course Mathematics 1. Students often criticize general courses for not preparing them directly for requirements of practice, but only for requirements of other courses within the school, which is the main task of general courses, namely, to create a suitable apparatus for professional, profiling courses. The content of these general courses seems to students to be complex, extensive and unusable. It is much more difficult for a teacher to keep students motivated and interested throughout the semester. Students often understand the meaning of the content years later.

Due to the way the curriculum of general courses is created, it is not possible to manipulate the content and scope of the curriculum. Space is created especially when choosing methods and forms of management of the educational process itself.

The content of the course Mathematics 1 is followed by other specialized courses. It is therefore essential that all students acquire knowledge, skills and abilities at the required level, which must be taken into account when implementing any modern method, form or principle in the educational process.

Mathematics at university builds language and thus a way of expressing oneself for professional and profiling courses. The basic course is followed by other courses using mathematical content, such as other general or profiling courses.

The requirements that are placed on the curriculum of the course Mathematics 1 can be summarized in three points:

- Requirements of the same course for follow-up knowledge.
- Requirements of advanced courses with mathematical content for knowledge, abilities and skills from the course Mathematics.
- Requirements of professional courses for necessary knowledge of mathematical apparatus.

The content of the basic course is mostly made up of two main areas of mathematics, namely Linear Algebra and the Function of One Real Variable. This content is usually divided into four modules, namely:

- Linear algebra;
- Numerical sequences;
- Function of one real variable and its differential calculus;
- Integral calculus of a function of one real variable.

At technical universities the so-called optimal content of the course Mathematics 1 is formulated, which is common for them. The scope of the course is determined by a specific university. Usually, this course is included in the first semester of the bachelor's study. The time allowance for the course in our conditions is two hours of lectures and three hours of exercises regularly during the 13 weeks of the semester and this scope cannot be changed.

An integral part of every educational process is feedback, i.e., student assessment. In the course Mathematics 1, the assessment is divided into two consecutive parts. During the education part of the semester, the student obtains the so-called continuous assessment (from which the student can obtain a maximum of 30 points) and at the end of the semester by passing the final test, the so-called final assessment (from which the student can get a maximum of 70 points). In order for a student to be admitted to the final test, the student must obtain at least 16 points from the continuous assessment, and in order for the course to be considered successfully completed, it is necessary to obtain at least 36 points from the final test.

Students from various types of secondary schools, whether from Slovakia or abroad, are interested in technical studies at universities in our conditions. These secondary schools have diverse specializations, to which they adapt not only the scope but also the content of the courses. Even schools of one type can be greatly differentiated.

These facts cause considerable heterogeneity of incoming students in their knowledge, abilities and skills, which is manifested especially in recent years and is growing significantly.

Our main goal is to increase the efficiency and attractiveness of the educational process itself by implementing agile methodology.

This goal is specified into the next research questions:

- RQ11: Which of organizational forms of work and teaching methods dominated during the education process at high school?
- RQ12: What kind of education do students expect from education at university?
- RQ13: Which of soft skills do students consider necessary to develop during studying at university?
- RQ2: How to re-design the course Mathematics 1 by implementing agile framework SCRUM?
- RQ3: What is the impact on the result of education in the pilot group of students after the implementation of the agile framework SCRUM?
- RQ41: Does implementation agile framework SCRUM improve the overall level of students' satisfaction with the course?
- RQ42: Do students think that after finishing the course Mathematics 1 with elements of the agile framework SCRUM, their soft skills have improved?

2. Course Mathematics 1 Re-Design

The course Mathematics 1 was divided into the following four modules, which are made up of units, while one unit has three lessons:

- Module 1—4 units Linear algebra—vectors, matrices, determinants, systems of linear equations
- Module 2—2 units Numerical sequences—numerical sequences in general, calculation of sequence limits. Function of one real variable—basic properties of a function, definition field of a function

- Module 3—4 units Differential calculus of a function of one real variable—derivation of a function and its properties, limits of a function, course of a function
- Module 4—2 units Integral calculus of a function of one real variable—methods of calculation of definite and indefinite integrals and their applications.

We built the method of teaching Mathematics 1 on three basic pillars (Figure 3): Lectures, Home learning and Exercises. Lectures on the course Mathematics 1 were realized in a standard, frontal form. Home learning is based on self-study of the individual with the use of additional electronic learning materials. These are videos and presentations for lectures, solved examples and simulations of problem solving. These materials are available to students on the course portal. The last pillar is the exercises that form the part of the course in which we have implemented agile methodology -framework SCRUM.

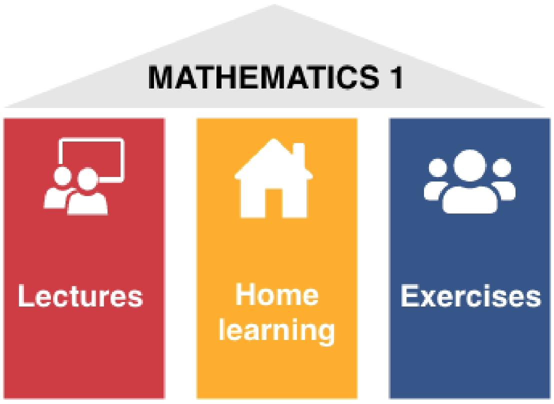


Figure 3. Mathematics 1 pillars.

The system of education in the course thus proceeded as in Figure 4. Given that Lectures and Home learning took place in a standard form, we will take a closer look only at the implementation of Exercises.

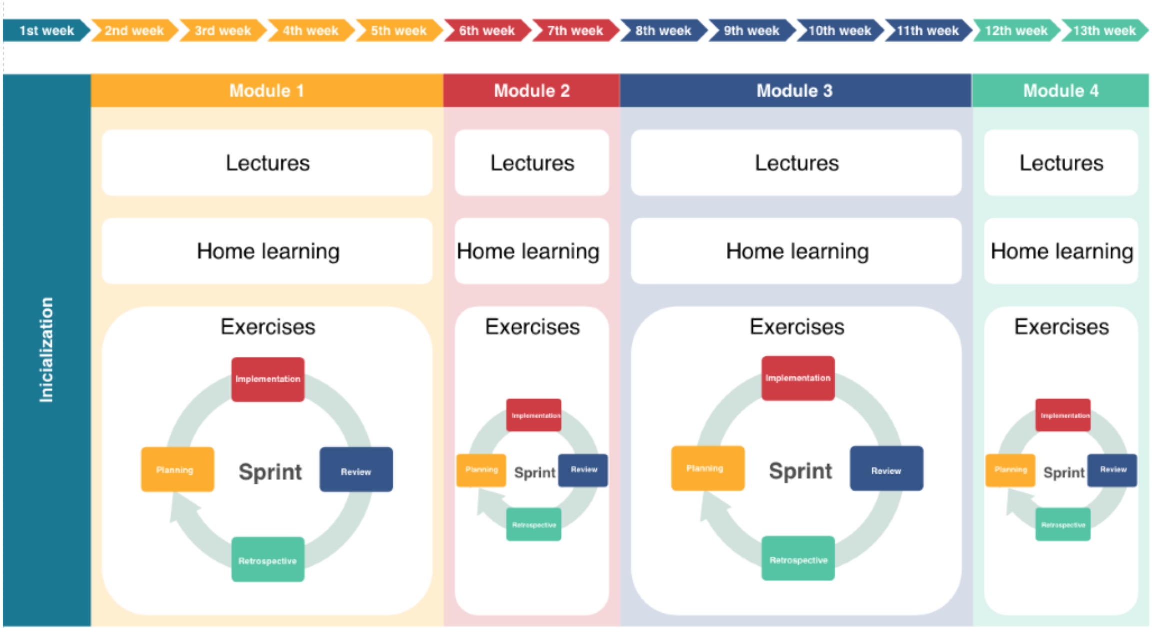


Figure 4. Mathematics 1—System of education.

As part of our implementation of SCRUM elements into the educational process of the Mathematics 1 course, the teacher acted as a Product Owner and partly assumed the role of Scrum Master. One of the students from each group acted as a spokesperson for the team, thus taking over certain roles and responsibilities of the Scrum Master. The teams had five members, and the team always had a student who had knowledge of mathematics at a higher level. Due to the fact that the teams worked together only during one semester, i.e., 13 weeks, we attempted to not change individual team members. In case the team did not cooperate (which also happened in our implementation) and did not progress, we recommended (based on our experience) reassigning individual members of the dysfunctional team (based on their choice and with the consent of other teams) or leaving the members of the dysfunctional team to work independently. Such interventions should be implemented as soon as possible, right after the identification of the problem.

The individual artifacts that are defined in the SCRUM are also in our implementation. The content of the course, knowledge and skills that the student has to acquire and to master form the Product Backlog. The Sprint Backlog basically consists of the content of individual Modules.

In SCRUM, the individual supplied functionality is described using User Story, which includes acceptance criteria. In education, its result defines the approved content of the course. Thus, individual User Stories are replaced by a task system. The system of tasks consists of follow-up tasks that are solved by each team member and tasks that are designed to practice and consolidate individual concepts or solution algorithms. A series of examples and a series of tasks are designed for each unit. Individual team members solve individual examples. The examples are designed so that the necessary mathematical apparatus is gradually built by them. Subsequently, a series of tasks suitable for practicing the content are proposed. While the individual examples are solved by all team members (to familiarize themselves with the necessary content), the Scrum Master can divide the tasks among the individual team members so that the acceptance criteria are met.

In practice, the acceptance criteria are a list of conditions that must be met in order for a User Story to be accepted as completed. They help to set the customer's product expectations correctly. In the school environment, the acceptance criteria are set by the teacher at the beginning of the semester. They reflect the requirements set by the teacher for students during the semester. At the end of each module, the student and the student´s team must demonstrate the relevant knowledge that is their Increment.

As mentioned, the individual content of the course was divided into Modules (Figure 4). Each part of the Exercises in a given module formed one sprint. The individual modules were adapted to the given topic and had a different way of assessment. Module 1 and Module 3 ended with an individual written examination. Module 2 and Module 4 ended with a team presentation on a given topic.

The first phase that precedes each model is Initialization:

- Teacher—within the initialization, the teacher introduces the students to the course schedule, method of teaching, acceptance criteria and method of assessment.
- Student—students, in cooperation with the teacher, are divided into teams and clarify the way of working on exercises.

Modules 1 to 4:

- Every Exercises week begins with Daily Scrum, where for each group its Scrum Master will tell what they have learned from the previous week, what the problem was and what they will do this week. If the problem occurs in all groups, the teacher solves the problem by direct frontal teaching of the part of the course. If the problem occurs in only one group, the teacher solves the problem in that group.
- In the sprint there is carried out Sprint Planning, Sprint Implementation, Sprint Review and Sprint Retrospective.
- Sprint Planning:

- ○ Teacher—determines the topic of the module, the system of tasks that students should know after the end of the module, defines the acceptance criteria and the method of assessment of the module.
- ○ Student—consults the study plan for this module, method of assessment, acceptance criteria, plans with his/her team the method of teaching.

- Sprint Implementation:
  - ○ Teacher—the teacher consults and mentors the teaching, if necessary, the teacher performs frontal teaching.
  - ○ Student—group work/learning, solving tasks and assignments, preparation for individual written examination or presentation.
- Sprint Review:
  - ○ Teacher—if the output of the module is a written examination, the teacher creates, implements and then evaluates it. If the output is a group presentation, the teacher will participate in the presentation and assesses it.
  - ○ Student—if the output is a written examination, the student solves it independently. If the output is a presentation, each student presents part of the assigned topic separately.
- Sprint Retrospective:
  - ○ Teacher—assesses the completion of the module, assesses the group and individuals, makes suggestions for improvement.
  - ○ Student—assesses his/her and the group results for the given module, proposes changes for the next module.

3. Materials and Methods

To increase the educational process's efficiency and attractiveness, the SCRUM framework has been implemented into course Mathematics 1. First, a questionnaire analysis of the current state was done to determine the answers to research questions RQ11–RQ13. Next, the course was re-designed (see chapter 2). An experimental (pilot) group of students attended the re-designed course during the first semester of the academic year 2019/2020. The pilot group consisted of 24 students (one study group) out of 143 first-year bachelor's students. After completing the course, the study results of the pilot and other groups were compared. To find out the answers to research questions RQ41–RQ42, another questionnaire survey was conducted with the pilot group of students.

The first questionnaire, asking for answers to RQ11–RQ13, was divided into three parts—general instructions, personal identification, and substance part of the questionnaire.

The substance part of the questionnaire was divided into three parts. The first part was focused on finding out the past experiences of students with teaching implemented in secondary schools (work organization, form, and process during lessons). The second part of the questionnaire paid attention to their ideas about modern teaching approaches they found interesting (organization of work, form and process). The third part focused on finding out which soft skills students would like to develop during their studies for their better future employment.

The second questionnaire was developed to meet the RQ41 and RQ42. The questionnaire was divided into three parts—general instructions, personal identification, and the substance part of the questionnaire.

It determined the satisfaction degree of students with the method of teaching, the achieved score evaluation of the subject, and whether their expectations relating to the development of soft skills were met.

Both questionnaires used unrestricted, semi-restricted and restricted questions. The Likert scale was used with the omission of the mean value (no/rather no/rather yes/yes). Questionnaires were designed and distributed to respondents in electronic form.

Descriptive statistics were used to meet the research question of RQ3. The results of the continual assessment (two tests) and the final assessment were processed between the pilot group and the other groups. Selected measures of central tendency (average, median) and measures of variability (standard deviation, coefficient of variation) were calculated for each of these groups. The calculated values were supplemented by graphical representation of the success of completing the course (pilot group vs. other groups).

Data Collection

The data were collected from first-year bachelor's students in the first semester of the academic year 2019/2020. This collection includes data from two anonymous questionnaire surveys and study results from the pilot and other groups.

Students completed the surveys anonymously using Google Forms. The first questionnaire survey was given at the begin of the semester and the second one at the end of the semester. The data collection includes 110 individual responses from the first survey, 22 responses from the final survey from the pilot group, 141 study results from other groups and 24 study results from the pilot group.

4. Results

As mentioned above, our goal was to increase the efficiency and attractiveness of the educational process through the implementation of agile methodologies. In the first step, it was needed to get information from students about the way of education implemented in their secondary schools, their ideas about modern, interesting education, abilities/skills they would like to develop for their better employment.

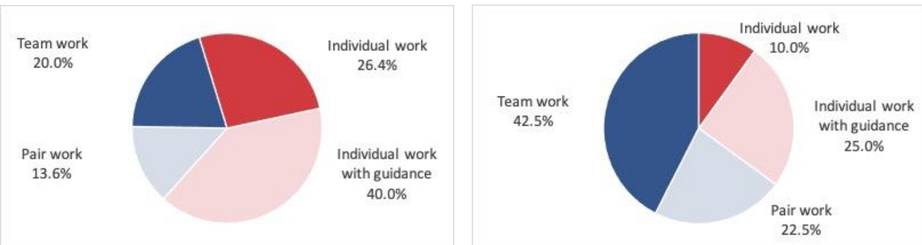
This was followed by a comparison of the use of agile methodologies in practice and in the school environment. These facts resulted in the need for change.

4.1. Analysis of the Current State—Questionnaire Survey (RQ11–RQ13)

A questionnaire survey was used to obtain information from students. The survey's main goal was to find out whether students are interested in changing the education.

The survey involved 110 students out of the total number of 143 students who entered the first year of bachelor's studies in a relevant academic year.

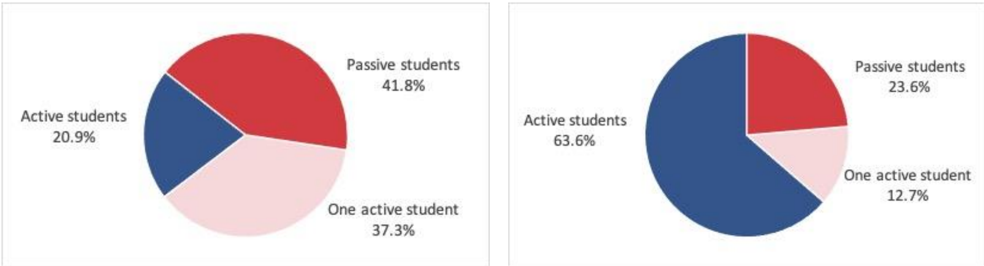
The results of the survey showed that the organization of work during their studies at the secondary school was dominated (66.4%) by the individual form of student work (individual work with parallel guidance by the teacher—40%, the teacher assigned a task that everyone solves independently—26.4%) (Figure 5a).



(**a**) previous experience (**b**) expectations

Figure 5. Results of the questionnaire survey concerning the organization of work during lessons.

The answers to the questions concerning students' activity during lessons showed that 79.1% of the students were passive (teacher solved the tasks and students rewrote them—41.8%, or one student solved the tasks and others rewrote them—37.3%). Only 20.9% of respondents stated that almost all students were active; these were students who had typically worked in smaller teams of 4–5 members and solved the assigned tasks together (Figure 6a).



(**a**) previous experience (**b**) expectations

Figure 6. Results of the questionnaire survey concerning the activity of students during lessons.

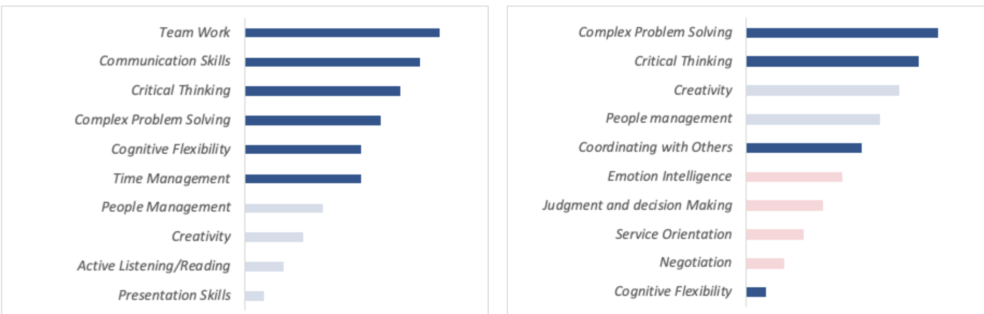
Despite the relatively high passivity of students, most respondents were satisfied with this teaching method in secondary school—73.6% respondents (Rather yes—50.9%, Yes—22.7%) in contrast to the remaining 26.4% respondents (Rather no—22.7%, No—3.6%).

The second part of the questionnaire found out how students characterized an interesting educational approach at university. The answers showed (Figure 5b) that up to 65.0% of respondents would prefer teamwork (42.5%) or work in pairs (22.5%), as opposed to 35.0% of those who would appreciate the possibility of individual work, whether alone (10.0%) or with parallel guidance of the teacher (25.0%).

Regarding the question of student activity during lessons (Figure 6b), the survey showed that up to 63.6 % would appreciate such an organization of work that all students are active.

Regarding the course of the lessons, students stated that they would like to be able to influence the course of the lessons (46.4%) and at the same time be able to have an individual approach of the teacher who takes into account the individual pace of the student (22.7%).

At the end of the questionnaire, students identified the 5 most important abilities/skills that they think should be developed during their studies for their later good employment. The results showed (Figure 7a) that they were mainly interested in developing the ability to work in a team, communication skills, the ability to solve problems comprehensively, creativity and the ability to actively listen/read with understanding. Three of the six most important abilities/skills selected by the students in the questionnaire are also in the top five listed as the 10 most important skills needed for being good in practice according to employers (Figure 7b).



(**a**) student's opinion (**b**) employers' requirements

Figure 7. Results of a questionnaire survey on the most important abilities/skills and comparison.

Based on these findings, we have decided to change teaching methods with an orientation towards the development of these abilities/skills as desirable and beneficial for all involved parties (students, and their future potential employers).

4.2. Comparison of Study Results of Groups (RQ3)

A total of 24 students were included in the pilot group. One student (4.2% of the total number of students included in the pilot project) did not obtain at least 16 points in the continuous assessment (CA) and was not admitted to the final tests (FT). One student (4.2%) failed the final test. To summarize, 2 of the 24 students in the pilot group failed the course (8%). The comparison group consisted of other students who completed the traditional course. This group was relatively larger, consisting of 141 students in total. Thirty-six out of 141 students (25.5%) did not get at least 16 points from the continuous assessment. A total of 18 students (12.8%) failed the final test. In the given semester, a total of 54 students out of 141 failed in the course (38.3%). The successful students included 22 students in the pilot group (91.7%) and 87 students in other groups (61.7%).

The success rate of students of both groups is shown in Figure 8.

(**a**) pilot group (**b**) other groups

Figure 8. Success rate of students.

The calculated selected basic statistical characteristics, such as average number of points, median, standard deviation and coefficient of variation for continuous tests (1st and 2nd tests), continuous assessment, final assessment, as well as the overall assessment of the course of both groups are for comparison in the following table (Table 1). It follows from the above that the pilot group achieved better results (higher average rating, higher median values) and at the same time there was lower variability of results in the group (lower values of coefficients of variation) in each monitored assessment.

Table 1. Basic statistical characteristics of assessment of the course Mathematics 1.

		1st Test	2nd Test	Continual Assessment	Final Test	Final Assessment
Average [points]	Pilot group	12.0	9.4	21.5	42.3	63.8
	Other groups	8.1	8.1	16.2	28.7	44.8
Median [points]	Pilot group	13.0	8.0	19.5	40.0	58.0
	Other groups	8.0	8.0	16.0	36.0	52.0
Standard deviation [points]	Pilot group	3.0	4.2	6.3	14.8	19.8
	Other groups	4.2	3.9	6.9	22.1	27.6
Coefficient of variation [%]	Pilot group	24.9%	44.8%	29.2%	35.0%	31.1%
	Other groups	52.6%	48.4%	42.8%	77.0%	61.6%

4.3. Questionnaire Survey (RQ41–RQ42)

After completing the course exercises (at the end of the examination period WS 2019/20), another questionnaire survey was conducted on a sample of 24 students of the pilot group, while the questionnaire was filled in by 22 students.

The above survey showed (Figure 9a) that 86.4% of respondents were satisfied with the form of completed course (yes—45.5 %, rather yes—40.9 %). Satisfaction with the obtained point evaluation of the completed course was expressed by up to 95.4% of respondents (Figure 9b).

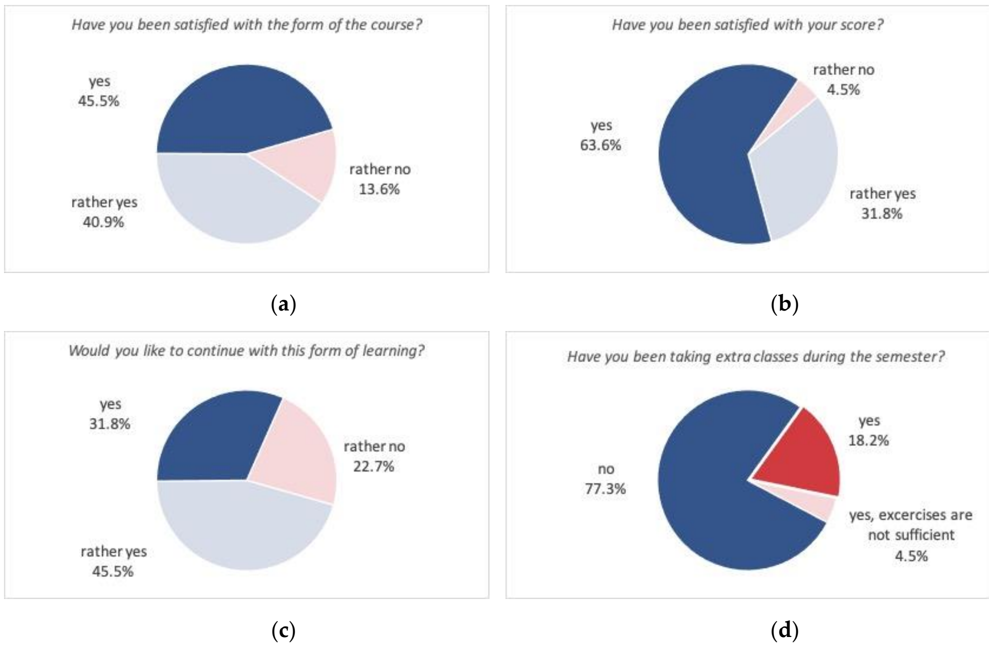


Figure 9. Graphic processing of the results of the questionnaire survey of the pilot group after completing the course.

When asked whether they would like to continue, in the given form of education, the course in the next semester, 77.3% expressed a positive (yes—31.8%, rather yes—45.5%), 22.7% stated the possibility rather no (Figure 9c).

When asked whether during the semester they used the opportunity to take tutoring in the course up to 77.3% of respondents answered "no" (Figure 9d).

Regarding the improvement of soft skills after completing the course, the prevailing opinion among respondents is that they have improved the following skills from the above options—communication skills (82%), teamwork skills (77%), presentation skills (73%), organizational skills (64%), independence (64%) and the ability to learn (59%).

When asked which of the 11 skills are important for a good job in the labor market and which method of teaching allowed them to develop these skills, in the first five places respondents mentioned expressive and communication skills, the ability to solve problems comprehensively (think, evaluate, solve problems), the ability to work in a team, creativity and organization and management skills.

After comparing the results of the survey in the pilot group conducted before and after completing the course, we came to the conclusion that the needs and expectations of students in terms of developing their skills were largely met (Table 2).

Table 2. Comparison of the results of the questionnaire survey before and after the implementation of education.

Before—What the Students Wanted to Improve	After Implementation—Which Has Improved
Teamwork skill	Communication skills
Communication skills	Comprehensive problem solving skills
Complex problem solving	Teamwork skill
Creativity	Creativity
Listening and reading skill	Organizational and management skills

5. Discussion

In the academic year 2019/2020, a pilot group of students was created in the course Mathematics 1, in which education took place using the agile framework SCRUM. In this section the impact of the implementation of the new approach is evaluated from three perspectives:

- Findings from this study versus the conclusions of other authors dealing with the implementation of agile methodologies in educational process.
- The teacher's view of education in the pilot group of students versus education in the traditional way of students.
- Our recommendations resulting from the implementation of experimental teaching.

5.1. Comparison to Related Work

Many universities implement agile methodologies into their courses. Most of them had analyzed the state of the industry and implemented either XP, SCRUM, Kanban or Lean into their software engineering or computer science courses. Examples of such implementations include Kropp and Meier [15], Wangenheim et al. [19] and Melnik and Maurer [18]. Their primary goal has been to prepare students for professional practice.

Some teachers implement these methods into other courses and subjects. Relevant ones include Vogelzang et al. [38], who implemented the Scrum methodology into secondary chemistry education, and Duvall et al. [36], who used their own method called Scrumage in the core course Discrete Math and eduScrum (mainly for primary and secondary schools) [37]. Due to the presented approach and the fact that all these works are based on Scrum, they all share similar roles, artifacts and ceremonies. However, there are some differences, e.g., the relevant works used fixed two-week sprints. In the presented approach sprints have two different lengths—four weeks for sprints which end with an individual written examination and two weeks for sprints which end with a team presentation. Scrumage also allows variable sprint length so that individual sprints can be "adjusted to fit the natural units of the course or chapters in a text" [36]. It also awards bonus points, that are not supported by the presented approach. EduScrum must be implemented as a whole and it does not specify details on how to implement it in the context of university education [37].

The presented approach did not focus on students' learning styles that of Scott et al. [28], who divided students into active and reflective learners. Their results showed that "students who received the class suitable for their learning styles achieved better educational outcomes" [28]. We, on the other hand, tried to include basic items of active learning in the education to suit students with all learning styles.

The presented approach did not cover all aspects of the Scrum process, but other works have the same result. It also did not provide a complex framework like eduScrum [37] or eXtreme teaching [35].

5.2. Education of Experimental Way versus Education of Traditional Way

From a questionnaire survey conducted in the pilot group of students, it can be stated that the students were satisfied subjectively with the implemented innovative educational approach, and objectively achieved better results on written examinations during continuous assessment and final testing in comparison with students who completed the course traditionally.

From the comparison of education in the experimental group and traditional way group from the teacher's point of view, it follows:

- students in the pilot group were more active than other students,
- the course of teaching is more dynamic,
- during the education process a positive working environment was dominant.

5.3. Recommendations

Based on our experience, the following recommendations are written regarding creating a team, visualization using a Kanban board and implementing other agile practices.

5.3.1. Creation of Team

The experience with agile methodologies applied in the educational process of the pilot group revealed the importance of the composition of teams. In order for the team to function in a self-regulatory manner and fulfill the set educational goals, it is necessary to divide students into teams so that they also include students who have basic mathematical competencies and are able to read and write a mathematical text. In our implementation, students were divided into teams (number of teams) at random. Some teams cooperated immediately (5 teams) while others (2 teams) could not cooperate and solve tasks in the required quality and within the specified time. These teams disbanded very quickly (some students dropped out for various reasons) and other members were redistributed to other teams, where the cooperation took place at a better level. After a short time, these students integrated, adopted the rules and way of working of the existing team and advanced together with the other team members.

Based on experience, we recommend that teams should not be created at random, especially when students do not know each other well and their basic level of knowledge, skills and abilities required for the course is heterogeneous. We recommend that students take a knowledge and personality self-assessment test at the beginning of the semester. Based on the evaluation of the results of these tests, individual teams were formed by the teachers.

When implementing any modern principles, methods or frameworks in the educational process, it is necessary to monitor the fulfilment of the educational goals of the individual, not just the team as a whole. At the end of the semester, each student must have knowledge and skills at the required level. As mentioned, there is a fundamental difference between implementing the SCRUM framework in practice and in the school environment. In the school environment, it is necessary to set up activities (processes) so that during one sprint, each individual acquires the set of hard skills. At the same time, it is necessary to create such an environment where soft skills are developed within the team as well as the whole group.

5.3.2. Kanban Board

The fulfillment of educational goals is one of the main pillars of the educational process. To monitor and visualize them during sprints, it is possible to use a Kanban board.

Kanban boards are used to visually represent the work at different stages of the process. The individual activities are formulated into tasks and each of the tasks is written on paper. Depending on the stage of solving the given task, the paper with the task is located in the appropriate column.

In the case of the educational process, it is possible to visualize the Kanban board:

- How the team works with the necessary activities and whether it can formulate them into clear tasks.
- How the team members share the individual tasks and whether this division occurs at all.
- How fast and if the educational process progresses within one sprint.

In practice, it moves the individual tasks of the Product Owner to the “done” column. In the school environment, we suggest leaving this responsibility to the members of the group. The check by the teacher would be only after the end of the sprint, either by an individual written examination, by a test or a group presentation.

5.3.3. Other Agile Practices Suitable

It is possible to involve other practices in the educational process, mostly coming from the XP (EXtreme Programming) method:

- Pair Programming—which means that two developers work together in developing on one computer. In education, this practice could be implemented by students working in pairs over one assignment/example and often taking turns and checking tasks together in a group. Working in pairs is efficient, as one counts and writes, the other checks and brings new ideas.
- Mob Programming—is a practice based on Pair Programming, not only limited to one pair of students, but to the whole team. In the educational process, this would mean that only one member of the team "writes", but they would of course take turns.
- Simple design—based on the idea that it is better to create functionality as simple as possible so that it can be easily changed when requirements change. In the educational process, there could be simple maps of solving examples created, algorithms for what can be most easily used in the calculation of a given problem.

6. Conclusions

Based on the changing practical requirements for the ability of university graduates, the arrival of a new generation of students at universities and their view of higher education, we implemented the SCRUM framework to teach the general course Mathematics 1. This paper describes our approach to implementing agile SCRUM into the educational process at the university, its impact on students' academic results, and their satisfaction with this realization.

Based on our experience, a description of circumstances when the mentioned implementation may fail (be unsuccessful) and the ways how to mitigate them is described. In chapter discussion, other possible agile principles that can be implemented in the educational process are described.

Based on the results (from individual tests and questionnaires) with the implementation of agile methodologies in the experimental group, it is desirable to change the method of teaching the course Mathematics 1 in the next academic year for all study groups and carry out an experimental case study. It is necessary to prepare a proposal for agile education for one of the following general courses (e.g., Mathematics 2) and observe whether the hard skills of pilot group students are more permanent and applicable to other courses based on the content of Mathematics 1. In the following research, it would be appropriate to use statistical tests to carry out the evaluation. These statistical tests could not be applied due to the unequal size of the compared groups. Also, the experimental group, as well as and the other group, should be approximately equal in size. However, it is problematic to ensure this condition in our circumstances since four different teachers are in the first grade. Seldom is one teacher assigned to a comparable group of students. The mentioned defects should be eliminated in future research to obtain certain relevant outputs. From a long-term perspective, it will be observed how students' soft skills change after the implementation of agile principles in several related courses.

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