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Challenges of Active Learning in a View of Integrated Engineering Education

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Abstract: The fourth industrial revolution has triggered a notable shift in engineering education, bringing the need to create new professionals. In this context, the active learning approach appears to be more important than ever. Nevertheless, to date quite lot of challenges related to active learning have been accumulated. Diversity of backgrounds and knowledge levels of students presented together in the same learning environment can become a source of dissatisfaction and failure for several groups of learners. To explore the reasons for these phenomena, the conduct of different categories of learners is examined and compared in terms of individual engagement and success in education. It is found that the student-centered approach is not necessarily the best method of teaching and learning when applied to students with great differentiation. A number of other conditions are required for success, namely, working in small groups, drawing on learner's abilities, individual instruction methods, etc. These conditions are analyzed in detail in this study. The need for a rigorous and systematic orientation of learners in a multidimensional educational environment is proposed as a prospective form and an integral part of the university staff activity.

Keywords: engineering education; integrated engineering; Industry 4.0; active learning; engagement

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1. Introduction

The fourth industrial revolution (Industry 4.0) is an ongoing technological, economic, and societal change affecting all enterprise activities, from operational daily work to strategic decisions, from technology to human behavior, covering the full supply chain and product life cycle [1,2]. Industry 4.0 is a specific framework for cyber-physical systems that combine and incorporate multi-disciplinary technologies whose design and analysis cannot be produced without a deep interaction of the physical infrastructure (physical layer) and information, communication, sensing, and control systems (cyber layer). In light of Industry 4.0, complexity of knowledge acquisition, representation, dissemination, utilization, and management increases along with integration of market, social network characteristics, and environmental factors that ensure transdisciplinary interconnections in science, technology, engineering, and mathematics (STEM) integrated in both the horizontal and the vertical dimensions.

The recent social, economic, and environmental trends pose new requirements to higher engineering education. Industry 4.0 has triggered a notable educational challenge, bringing the need to create a novel type of engineer, unknown a decade ago. Many authors, for instance [3,4], believe that this paradigm is not viable without the so-called T-shaped engineers, who should have not only in-depth knowledge of their own specialization (the vertical part of "T") but also skills in communication and collaboration within multidisciplinary teams (the horizontal part of "T"). New requirements to professionals cover at least four core competencies: technical, methodological, social, and personal [5–7]. Technical competence presumes not only high professional knowledge but also enhanced info-technological skills, including cybersecurity and media issues. Methodological competence comprises creativity, problem and conflict solving, decision-making, research experience, and strong efficiency orientation. Social competence implies intercultural and language skills, communication and networking experiences, teamwork with leadership, knowledge transfer and cooperation abilities. Personal competence is based on flexibility, tolerance to a job and task change, and interest to learn. In terms of these new competencies, the community faces the need for a prompt reform of higher education, especially crucial for engineering which turns now from narrowly focused to integrated engineering.

Respectively, educational methodologies are changed in conjunction with technological and market developments. These include the introduction of new specialties, curricula, and courses, transformation of older ones, and improvement of certification and assessment approaches [8]. Recent interdisciplinary studies reflect the innovations in training systems, the changing attitudes of engineering students, and the role of STEM [9]. Many companies urgently upgrade the skills of their employees in cost- and time-efficient ways [10].

Since society is entering Industry 4.0, active learning (AL) educational methods appear to be more important than ever. By definition [11], AL is a student-centered approach, which encourages learners to take ownership of their own educational experience. Being based on learning and social constructivist theories, AL aims to promote students' interest and responsibility in the construction of their own knowledge through concrete experience. For this, the teacher acts as a facilitator converting the learning into an authentic, exciting, and meaningful process. The key AL goal is to bring students into problem solving, especially in complex situations that require collaborative efforts, joint reflecting on, and negotiating about the strategy and intended outcomes. Many researchers, such as [7,10,12,13], consider AL especially positive for engineering subjects. They claim that switching from lecture-based frontal teaching to AL develops deeper understanding of theory and practical applications, allowing students to formulate, realize, and validate ideas in a more holistic manner. The role of lectures is converted to providing tighter interconnection of concepts in terms of the materials and processes [12]. AL often includes student polling with debates, role enactment with peer-teaching, daily journals or mini-projects in class, and similar activities. From a purely summative assessment based on individual written exams, AL proceeds to types of formative assignment with feedback, in which students are continuously aware of their academic progress. This assessment excites and boosts education thanks to fast grading, estimating students' achievement, and supporting learning [14].

Experiencing such AL varieties as project-based learning, team-based learning, outcome-based learning, learning by doing, and distance learning including blended (or hybrid) training and flipped classrooms, numerous student cohorts confirm that these approaches are beneficial in solving the problems directly linked to the specific topics and projects [7]. The experience gained over the years of running team-based learning shows its relevance for the cooperative model due to the clear division of roles [15]. In project-based learning, students often achieve different maturity levels and technical skills according to their duty in the project [16]. The blended learning approach, where the staff combines different distance learning activities with traditional face-to-face methods providing some mix of real and virtual sessions [17], is suitable for session-based education. In the flipped classrooms, considered as a kind of blended learning, much of the study materials and technical tools are available for students outside the classroom via virtual platforms, cloud sharing, or online learning management systems. Instead of traditional lectures, the flipped classroom meetings are organized in the form of brainstorming and problem-solving discussions, thus promoting AL in the presence of a teacher.

However, quite a lot of challenges related to AL have been noted to date. There are not that many teachers deploying this new medium in the classroom directly and, consequently, only several categories of elect students benefit from the numerous AL-enriched offers [10].

Although AL seeks to broaden technical and human interpersonal skills, in fact, some students have difficulties dealing with heterogeneous and multidisciplinary problems whereas others find it hard to cooperate in multi-disciplinary teams [18]. In [16], the learners identify the following drawbacks of the team-based approach: (a) a presence of in-group conflicts and difficulty in their management, (b) inequality of interest within teams, and (c) increased and excessive workload compared with traditional learning. According to the analysis conducted in [17], the majority of the participants indicate such "passive" tools as webinars with asynchronous recording of laboratory demonstrations as preferred and more satisfactory methods than such advanced AL types as online direct connections with the laboratory stands, despite the availability of manuals and tutorial aids.

Several researches point out that student performance in AL mostly depends on final grades instead of just knowledge delivery, deepening, and systematization, and fades out without rewarding [12]. The outcomes of [18] yield no significant change in learning outcome between students that did mandatory assignments and students that were given autonomy and freedom. These results are consistent with [19–21] that demonstrate that formative assessment provides positive results only for students that are open for feedback. However, many students are often happy to be free from mandatory assignments and spend their AL resources on checking whether they achieve enough high grades rather than skill or knowledge. At the same time, formative assessment requires consistent feedback from academicians aiming to inform students of their knowledge weaknesses, direct them in further learning, and provide specific insights on how to improve learning [14]. Such valuable feedback is a challenging issue resulting in an overload for teachers, especially in crowded classrooms.

It seems that an initial assumption that AL is the best educational technology is invalid globally, and does not apply to all groups of students, teachers, and tools. There is a need to explore some educational obstacles more carefully and to quantitatively assess the outcomes of AL.

Current research continues the series of earlier published studies [13,22,23] on the challenges facing AL and represents yet another attempt to understand to what extent it is possible and valuable to offer an AL approach. This time the focus is on integrated engineering education, able to match technological and market requirements posed by the fourth industrial revolution.

From one side, traditional face-to face courses, even supplemented with digital technology and such tools as presentations, online tests, etc., are considered as rather conservative, with a low level of active student commitment [17]. Almost no researchers now put emphasis on the use of direct, teacher-centered instruction instead of AL. From another side, the full-scale AL presented, particularly, in massive open online courses (MOOCs) is not effective as evidenced from its high dropout rates [24]. As pointed out by several studies, such as [25], only about 10% of the students who enroll in MOOCs actually finish them.

Taking into account that there always exist cases of "inconsistent" students that perform well in one environment and poorly in another, this research is focused on the impact of AL on various categories of students, differing in background, specialty, type and length of study, and language proficiency.

The study aims for evaluation of at least two issues related to multidisciplinary professional training in light of integrated engineering education: student engagement in AL and student success in AL. Here, those students are called motivated who participate in several AL activities and devote a sufficient amount of learning time to them (at least half an hour weekly). The number of AL forms they participated in is called the degree of engagement. The participants considered successful are those who are awarded level 4 or 5 on the 5-score grading scale in a particular AL form. The learners whose grades are below 4 are regarded as unsuccessful.

The additional goal of this research is to identify a flexible AL framework suitable for those students who exhibit difficulties in learning.

Further, the learner's contingents and disciplines focused in this research are described in terms of the study forms, tools, and AL methodology used. Then, the research methods and resources are introduced. Next, the results obtained are presented. The following discussion of findings and important questions is based on the information retrieved.

Finally, an optimal learning framework is discussed in conjunction with technological and market requirements posed by the fourth industrial revolution.

2. Materials and Methods

2.1. Students and Disciplines

Two engineering specialties fall into the focus of this research, in total, about 80 students at the Engineering School in Tallinn University of Technology. The first specialty is "Integrated Engineering" for the third course of the daytime bachelor study form (IEB) designed specifically to meet the requirements of the interdisciplinary education needed for the Industry 4.0 era. The IEB syllabus involves the broad list of disciplines that do not belong to a single department, as is usually the case, but are disseminated among the school departments and, partly, among other schools, including the School of Information Technology and School of Business and Governance. The second specialty is "Production Development and Product Engineering" for the session-based master study form (PDM). The PDM syllabus is based on the School of Engineering resources. Appropriately, two disciplines are addressed in this paper: "Robotics" (ATR0030) for two IEB groups and "Industrial Automation and Drives" (EEV5040) for one PDM group, each of six credit points in the European Credit Transfer and Accumulation System (ECTS). The language of instruction is English which is a non-native language for all participants.

Nearly half of students have enrolled on these courses because they are trained in one of the above specialties (compulsory discipline). Almost the same number chose these courses as elective disciplines in the specialization. Most of them are Erasmus+ European students or non-EU students from Georgia, Ukraine, Russia, and other countries. It is noteworthy that participants with diverse backgrounds and even different knowledge levels were present together in the same learning environment as a multifaceted cohort oriented to the needs of Industry 4.0.

2.2. Learning Environment

Despite the difference in disciplines, learning outcomes, study forms, and lengths, the learning environments of both courses were organized in a similar way and both syllabi were comprised of compulsory and optional parts. The former provides learners with the minimal volume of knowledge and professional skills whereas the latter is called on to enhance and deepen them in conformity with the requirements of Industry 4.0. Both courses have been incorporated into various AL sessions, practices, and polls. Thereby, all students could participate in most AL activities, including blended learning in online and offline lectures and student presentations, learning by doing and team-based learning in real and virtual labs, project-based learning in computer exercises, and outcome-based learning via individually chosen assessment methods. As the mission of a university is to provide a safe, sustainable, and accessible way for learners to come together and interact as an educational community, the studies were conducted in a blended manner. For this purpose, the students studying in person and by distance learning could be supervised at the same time and the session types were explicitly designed to make the most of both online and place-based knowledge acquisition. Figure 1 introduces the study forms and assessment methods used.

Table 1 demonstrates how the most important (in view of Industry 4.0) learning outcomes are related to methods and tools used to achieve these outcomes and assess the results.

The bulk of lectures were delivered in class, aiming to involve the learners in the highlighted discipline features, to present the Internet and library resources, to underline learning goals and methods, to introduce an assessment system, grading rules, and progressive learning technologies. Several lectures were given online, via Microsoft Teams™, being accompanied by slideshows, videos, and demonstrations in the university learning management system Moodle™.

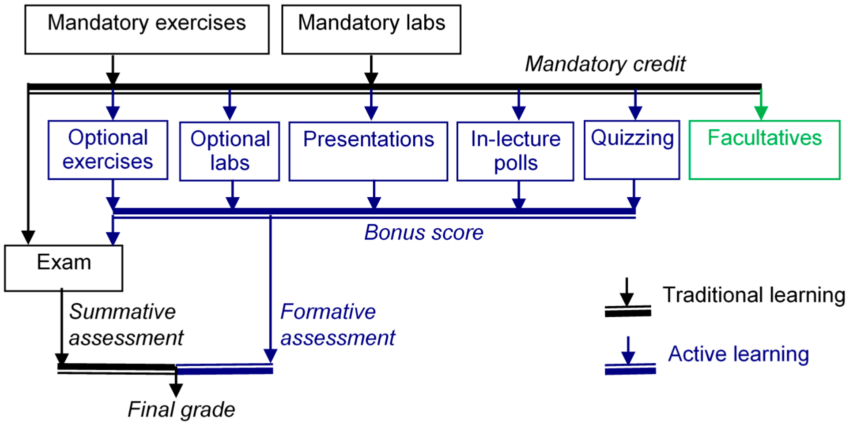

Figure 1. Forms of study and assessment methods.

Table 1. Distribution of the most important learning outcomes in view of Industry 4.0 among forms and tools of study, assessments, and AL methodologies.

Learning Outcomes	Forms and Tools of Study	Assessment and AL Methodologies Used
1. Acquiring knowledge of automata and robot topologies, coordinate transformations, forward and inverse kinematics, statics, and dynamics.	Lectures, mandatory parts of computer exercises with Matlab™ and Robotics System Toolbox™.	Optional part of computer exercises in Simulink Simscape™ with individual reports and quizzes (project-based learning), or exam.
2. Getting knowledge of machine and robot types, leading companies, markets, and applications.	Self-learning via Internet, textbooks, and e-books.	Student presentations, discussions, quizzes (goal-oriented learning), or exam.
3. Gaining skill in communication and problem solving in complex situations related to automation and robotics.	Self-learning via Internet, textbooks, and e-books.	Discussions, on-lecture fast-track polls (situation-based learning), or exam.
4. Obtaining experience in programming and control.	Labs with Mitsubishi and ABB robots, Ciros Studio™, and RobotStudio™.	Personal reports on individual lab tasks (learning by doing).
5. Developing habits in collaboration and management within multidisciplinary teams.	Labs where experiments and measurements are performed collaboratively and results are then compared.	Reports with individual data processing and calculations (team-based learning).

Regular on-lecture fast-track polls were conducted in the FASMI (Fast Analysis of Shared Multidimensional Information) style and involved: (a) intelligent tasks, (b) gathering audience answers, (c) explanation of the correct answer, and (d) winner grading. They engaged students' attention and their desire to participate in such optional in-class events as lectures and presentations, because success in these options was rewarded by bonuses that learners collected during the semester to form the basis of their final grade.

Course syllabi specify the compulsory knowledge of different types of automats and robots. To exclude them from the examination load, interested students were requested to design and submit short (10–15 min) Power Point™ presentations, either in class or online via Microsoft Teams™, which covered important topics of the syllabus that could be either chosen from the proposed list or suggested by learners themselves. The content of presentations included the placement of the studied object (robot, machine, device) in general topology classification, application area and examples, most popular companies and their models, history of developments and perspectives, technical parameters, sensors and actuators, control and programming, advantages and disadvantages, etc. For student presentations, a portion of lecture time was reserved weekly. As a rule, post-presentation discussions followed every demonstration. In this way, presenters not only passed a part of exam requirements but also helped others learn their topics. Like other study materials, student files were stored in the Moodle™ repository and could be requested by learners and teachers. For that, they were supplied with the copyright protection attributes (name, pre-recorded audio, photo, and date).

Lectures, both the offline and online ones, were accompanied by online quizzes, in which students could optionally participate. Each quiz, composed of 10 questions, was open in Moodle™ during a lecture week (7 days, from Monday to Sunday midnight). To answer, the respondents were asked to choose 1 to 4 options that they considered right, using any complementary sources (books, Internet, cheat sheets, consultations, etc.). Every correct answer increased the individual bonus, whereas every wrong one decreased it. Hence, the quiz score could vary from negative to positive. The number of attempts was not limited while the quiz was open. After the quiz closed, the last attempt was counted and the results were published along with correct answers.

Computer exercises were authorized to be produced either in class or at home. However, the compulsory segment of exercises every student was supposed to demonstrate face-to-face and to report individually. In addition, each exercise included an optional mini-investigative part in a project-based format, in which solutions brought bonuses as well.

The labs were arranged as team-based strongly scheduled events accompanied by the preliminary polls, clear role distribution, individual tasks, and personal reports.

An assessment system was accomplished with formative and summative grading capabilities, shown in Figure 1, from which each student could choose one or the other way of learning. The integral bonus score in the form of the rounded-up weighted sum of quiz scores, exercise options, lecture activities, and presentation grades was considered as an expected exam grade or part thereof. However, instead of the bonus sum, every participant could also take an online or offline traditional exam covering the full course, without any complementary sources. For the exam preparation, the questions from all past quizzes, polls, and tasks were open for an unlimited number of attempts at solving them with immediate feedback in the 5-score grading system, where each trainee could submit his/her results as many times as he/she wanted. These training scores did not affect the grade, but helped those learners who were not satisfied with their current bonus sum to prepare for an exam.

2.3. Methodology and Resources

In pursuit of the objective set in this research, substantial data arrays were processed. First, to analyze the AL results, from the total mass of learners only those were selected who had chosen the student-centered approach over the traditional teacher-centered instruction. For that purpose, a separate webpage was established in Moodle™, where only those were welcomed to enroll who intended to solve optional tasks.

Then, the focus was directed to the reasons that encourage students to choose AL. Since the promised knowledge and skill outcomes were announced in the course syllabi, only one of the two following reasons might fuel this desire: either to achieve broader and deeper outcomes or to be graded higher and in an easier way. In the former case, outcomes meant knowledge and skills, whereas in the latter, outcomes meant grades. To resolve this issue in a scalable manner, all AL activities were roughly divided into three categories: long-term actions, short-term events (brainstorming), and facultative ones. Post-lecture quizzes and optional exercises came under the first category as they provide a lot of time to solve them, while requiring perseverance and patience. The second group involved in-lecture polls and discussions with speakers founded on quick thinking, boldness, and decisiveness. Student presentations fell into the second category as well, as they need the desire for finding impressive facts and creating attractive slideshows and videos. Non-scalable participation in company practice, enterprise visits and excursions, exhibitions, and guest lectures were assigned to the facultative activities. Based on this division, a comparison was made between the full number of "active" learners and those interested in the facultative AL events. Thus, an attempt was made to understand the meaning of the outcome-based learning from the students' perspectives.

Next, participants were identified who had succeeded in different forms of AL, including the long-term (quizzes, exercises, and presentations), the short-term (polls, discussions), and the facultative ones. Along with them, the students unsuccessful in all forms of AL were separated as well. These results were then related to the time intervals that the learners devoted to optional activities. Since the most of participants succeeded in only a few forms of AL, an attempt was made to link these forms to well-known learning styles, seeking to explain the reasons for this partial success.

During the study, three categories of data sources were examined and processed. The first group represents exam grades along with the feedbacks and comments of participants stored in the university OIS™ study system. The second resource is a voluminous database of logs, activity reports, course participation lists, statistics, and event monitoring rules comprising Moodle™. The third one is the authors' collection of their own statistics published during the recent decade in over 30 conference presentations, research articles, and theses, including [13], related to AL.

3. Results

Figure 2 demonstrates the relationship between three categories of students: (a) those who have not chosen AL, (b) whose who have demonstrated that their learning is directed to obtain professional knowledge and skill, and (c) students whose outcome is restricted by the final grade. The grey sector shows the percentage of students who did not register on the site with additional tasks or, despite the registration, did not participate in any of the activities there. The red sector represents the percentage of participants in at least a half of the facultative events. Others are represented by the blue sector.

Next, the time that students devoted to the long-term AL activities was estimated. Quizzing time was recorded directly by Moodle™ statistics tools. Exercise time was also estimated by Moodle™ as intervals between task commencement and deadline points. Time needed for the presentation development was self-assessed by the students. Given that each discipline is designed for 156 h (six credit points in ECTS), including 64 h of classes, the rated time for all AL forms was considered as 92 h. In Figure 3, time devoted to long-term activities and its polynomial trendline is superimposed with students' final grades.

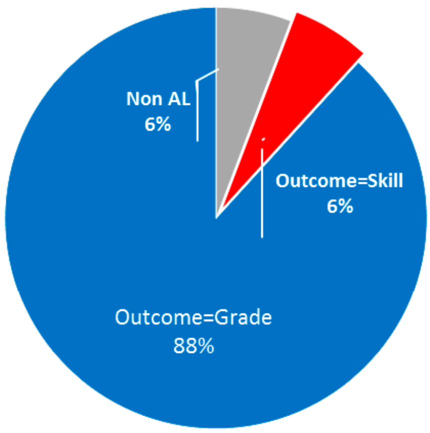

Figure 2. Percentage of students who have not chosen AL (Non AL), students whose learning is directed to obtain professional knowledge and skill (Outcome=Skill), and students whose primary target is the final grade (Outcome=Grade).

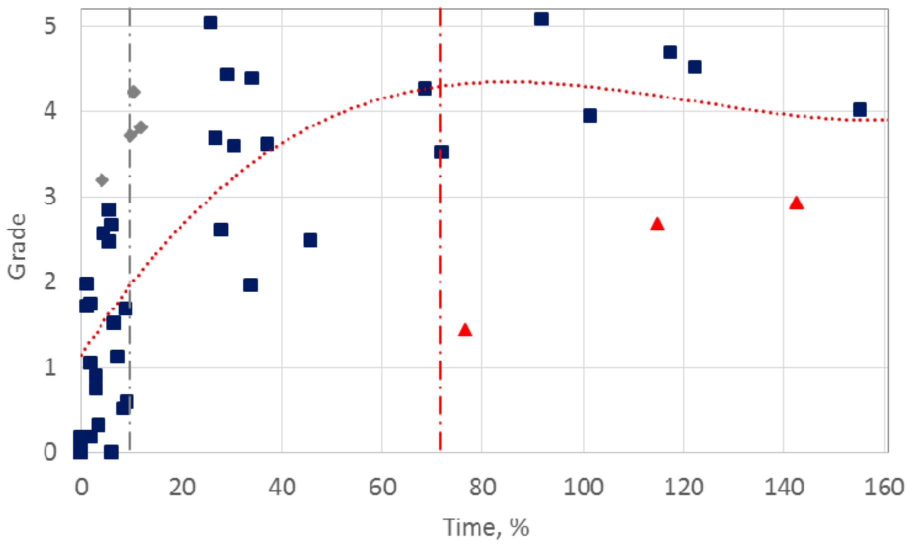

Figure 3. Dependence of students' final grades on time devoted to the long-term AL activities, and the polynomial trendline.

Using Figure 3, all students are further divided into three cohorts: those who devoted above 70% of the rated time to the long-term activities (the right half of the diagram), those who spent less than 10% of time for AL (the left area of the diagram), and the remaining students. In Figure 4, the appropriate percentages are shown.

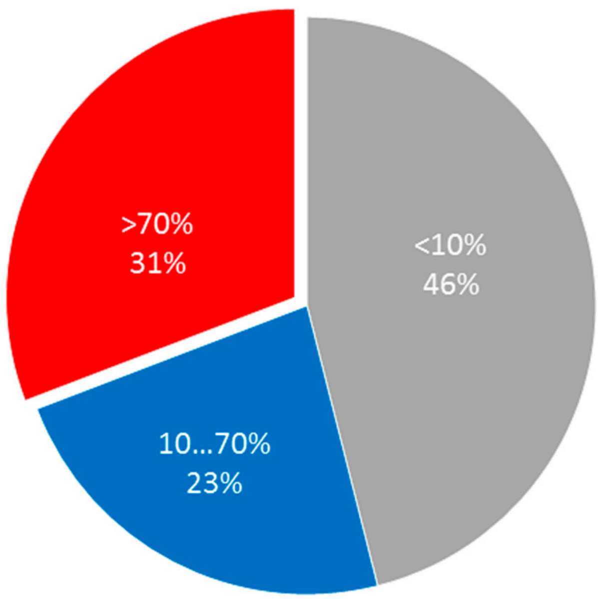

Figure 4. Time slots of the long-term AL options: percentage of students who spent above 70% of the rated time on AL (red), percentage of those who spent less than 10% of the rated time (grey), and percentage of the remaining students (blue).

Those who used less than 10% (a few minutes weekly) could not be considered as real AL participants though they are presented in the AL group in Figure 2. Therefore, they are not included in further diagrams. Starting from 50%, the mean grade actually does not depend on time. However, the AL workload above 70% draws particular attention as it may prove to be increased and excessive compared with traditional learning, thus resulting in a reduced number of AL forms they participated in called "a degree of engagement" in the introduction.

Figure 5 shows the dispersion of AL participants over the five AL forms along with their success. Here, only those students are taken into account, who devoted above 10% of time to AL. The red bars show the percentage of students who have been awarded level 4 or 5 on the 5-score grading scale in a particular form of AL. In the introduction, these students were called “motivated”.

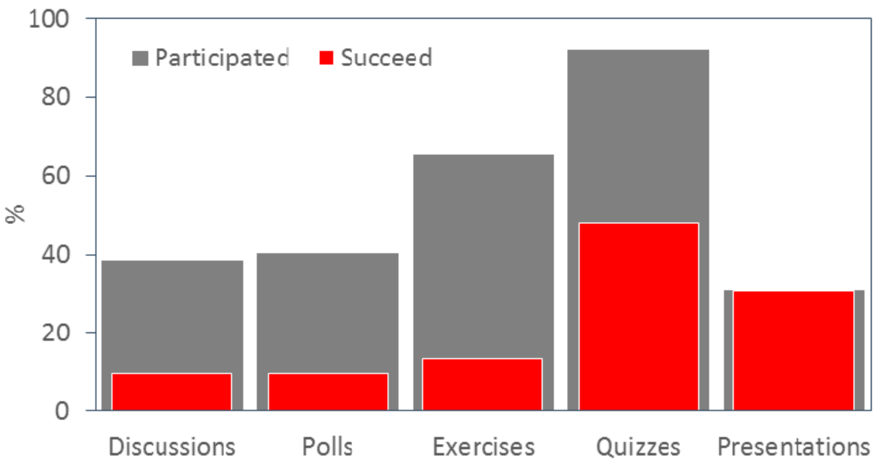

Figure 5. Dispersion of AL participants over five AL forms and percentage of successful participants.

As different numbers of students participated in various forms of AL, Figure 6 demonstrates how the number of AL forms (degree of engagement from 2 to 5) correlates with the number of participants in these forms along with the time they took and their final grades.

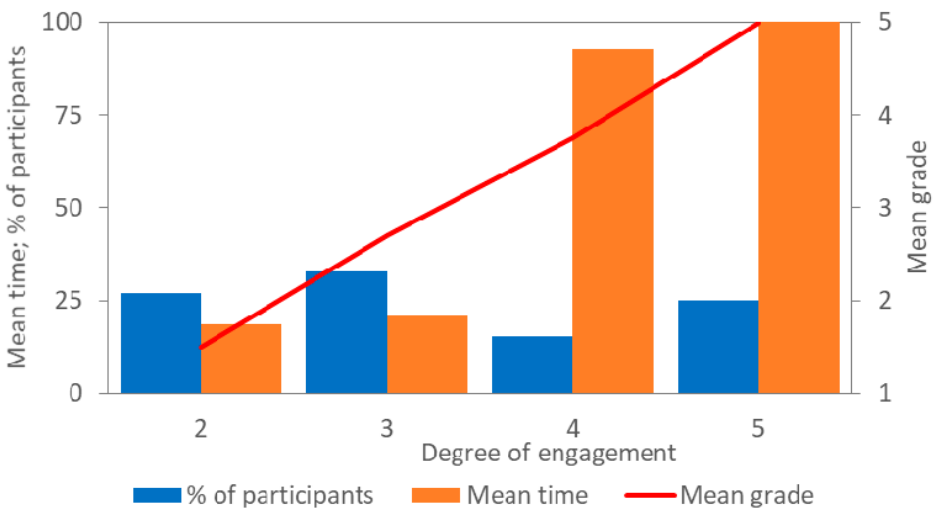

Figure 6. Dependence of mean time used for AL, percentage of participants, and mean final grade on student degree of engagement.

In Figure 7, four groups of students are presented: (a) those who succeed in three or four activities simultaneously, (b) who succeed in two activities, (c) who succeed in one activity, and (d) who have not been included in the previous groups. The ring that frames the chart of student success contains the percentage of corresponding final grades, from 1 to 5. In this way, a success in AL is linked with a final success in learning.

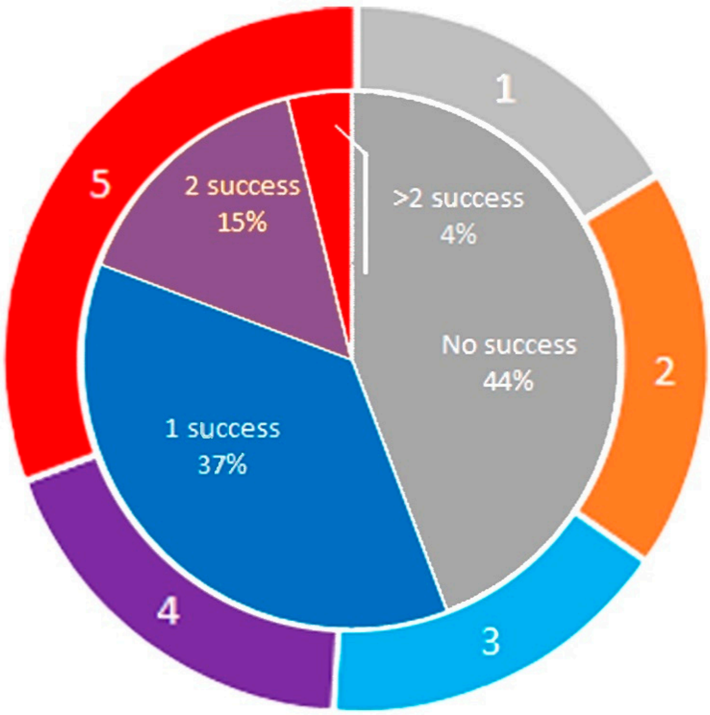

Figure 7. Student success in AL: percentage of students who succeed in three or four activities simultaneously (>2 success), in two activities (2 success), in one activity (1 success), and who have no success at all (No success). In the bordering ring, the corresponding proportions of final grades are allocated.

4. Discussion

Both the positive and negative sides of AL were recognized in this research. It is pleasing that most students volunteered to participate in AL, regardless of their specialty, form of study, and background. The fact that there now exist many AL methods and approaches is positive, and students and instructors may choose those that will better match their interests and abilities. Since all the described activities have a high focus on AL, but are built up in a different manner, they open multiple ways for reaching the prescribed learning outcomes.

Nevertheless, Figures 5 and 7 display the troubling issue that a significant proportion of learners, who volunteered to participate in AL, were unable to succeed there. As follows from the results obtained, student failures weakly depend on time used for AL (Figure 3) and forms of AL (Figure 5). They do not depend on student understanding of the meaning of learning outcomes, whether they relate to better knowledge and skill or to the final grade. They are also independent of the form of study, whether it is a daytime or session-based study, a bachelor or master study.

The potential sources of the learning success or failure often cited are differences in personality traits, prior knowledge, language proficiency, and cognitive capabilities summarized usually in the term "learning styles" [26]. However, the authors' attempts made to connect the troubling obstacles with the learning styles do not provide any reasonable explanations of the results found. The model [27] distinguishes four bipolar dimensions of learning preferences, which can be seen as a continuum: (a) active vs. reflective, (b) sensing vs. intuitive, (c) visual vs. verbal, and (d) sequential vs. global. In [28], four other learning styles are presented, two of which focus on how experience is gained, while the other two are oriented towards how experiences are processed subsequently. They are: (a) concrete hands-on experience in direct contact with other individuals, (b) reflective observation through concept understanding based on the observations made, (c) abstract conceptualization via developing abstract concepts by scrutinizing ideas using logic, and (d) active experimentation, in which learning is accomplished in an active exposure to problems and deriving practical applications or solutions in groups. In [5], these learning styles were successfully applied in the inter-university masters course "European Engineering Team". The authors of [29] identify similar styles, namely activist, reflector, theorist, and pragmatist. In total, all above models rely on self-assessments and consist of combinations of bipolar learning dimensions. The taxonomy of [30] also divides the knowledge domain into four types of knowledge: factual, conceptual, procedural, and metacognitive. Factual knowledge refers to the basic knowledge students have to be acquainted with a discipline or to solve a problem in that discipline. Conceptual knowledge refers to the interrelationship between the basic facts forming a bigger conceptual structure. Procedural knowledge refers to information that relates to doing something and using developing skills, methods, techniques, and algorithms. Metacognitive knowledge involves the broad area of cognition in general as well as self-awareness.

All the above styles more or less successfully explain the behavior of those students who succeed in one or several AL activities, but only slightly cover unsuccessful participants. Insofar as the courses are targeted to the particular learning outcomes irrespective of learning styles, significant challenges are observed in learning that often lead to student and teacher dissatisfaction [28,31].

In order to inspect the sources of success and failures in AL, four groups of learners shown in Figure 8 are further highlighted based on Figures 5–7. This categorization seems suitable to compare students depending on their individual engagement and success in learning.

Groups I and II involve the students successful AL, whereas groups III and IV unite unsuccessful participants, drawing on the number of successes from Figure 7. The members of Groups I and IV demonstrated their engagement to learn, whereas groups II and III were indifferent, meaning the degree of engagement used in Figure 6. Therefore, the ratio of the motivated and indifferent learners complies with Figure 6, whereas the ratio of successful and unsuccessful students matches Figure 7 in this particular research, but may vary in other obstacles.

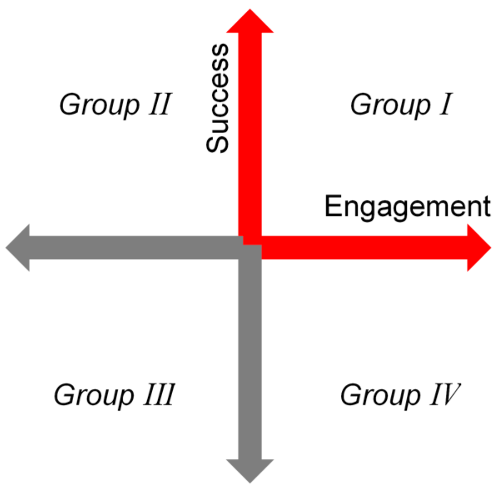

Figure 8. Groups of students depending on individual engagement and success in learning.

Group I mostly involves the students falling into the red, purple, and blue sectors in Figure 7. These successful students are especially progressive in AL, interested in learning and in their subjects, they learn well. They thrive on painful tasks and difficult questions, initiate discussions, do not dwell on problems, and do not push them away. They do not stop on mistakes. Instead, they look at these mistakes as normal moments in achieving their goals, accept them, and learn from them. Results obtained in this research demonstrate that they usually succeed in several AL activities. Continuous summation of bonuses from all activities into the final grade has a high impact on these students thanks to their analytic and quantitative potential. The student-centered approach helps them in developing high-order cognitive skills such as the ability to understand, synthesize, evaluate, and create [32].

However, despite poor perceptions and lack of interest in engineering and science jobs, weak applicants also enrolled in the courses under discussion. They are represented in other quadrants of Figure 8.

Participants of Groups II and III demonstrate their disinterest towards the subjects, have no habit of hard work and do not have enough patience for long-term activities. Most of them fall into the grey sectors of Figures 4 and 7. As follows from Figure 4, the average time they spend on the course is much less than the strong learners.

Group II is formed of the "grey" participants who achieved grades of 3, 4 and even 5 (the latter are labelled by the diamond markers in Figure 3). They are able to obtain fairly good summing results in AL and in summative assessment, often thanks to their effortless abilities in cheating and accessing classmate help, though failing in personal quizzes and fast-track polls.

Group III represents the candidates for dismissal because of their error in choosing the specialty or other social or mental reasons. This seems normal because not everyone can be strong in everything.

The students of Group IV attract the growing interest. They are drawn in either the blue or the grey sectors in Figure 7, or in the red sector in Figure 4 (the latter are labelled by the triangle markers in Figure 3). They are usually called "weak" or "slow", which typically means not being able to cope with studies or finding it difficult to understand the subjects. It is explained in [33] why the members of Group IV are motivated to learn but have no success. Obviously, these students with low success in AL can benefit not from bonuses but from constant teacher feedback, which aids in their learning, improves their knowledge acquisition, and increases their final grades. In this case, there is no point in talking about AL. When informed about their weakness, they are ready to put in effort to learn the subject.

Therefore, in contrast to Group II of uninterested learners and Group III of inapt ones, instructors are very responsible for helping to aid these students in their studies. Even in these circumstances, students could be motivated by different things, and a variety of educational approaches have to be kept in mind when designing the study rules. However, AL and its benefits are not warranted by the mere introduction of different options in the course; rather, a number of other conditions are necessary for that, namely, working in small groups, individual instruction methods, problem-based or project-based and learner-centered scenarios [12]. Quizzes are a suitable tool to inform weak students of their performance throughout the learning process, promoting their self-regulation and regular work over the year, instead of formative assessment. To assist the slow students and to allow the deepening and systematization of their knowledge, such materials should be available in Moodle™ as solved exercises and explanations from teachers and staff. These students can be encouraged to participate in the optional classes by suggesting solutions to the exercises and by criticizing the results [34].

5. Conclusions

Based on the requirements posed by the fourth industrial revolution, an impact of AL on different student groups has been evaluated in this research. Among the positive sides of the student-centered approach, most students volunteered to participate in AL because using multiple methods and approaches can better match their interests and abilities. Nevertheless, several troubling issues were found.

As follows from the results obtained, student failure weakly depends on time used for AL, on AL activities, on student understanding of whether the learning outcomes relate to the knowledge or to the final grade, on the form and the level of study. Known theory of learning styles more or less successfully explains the behavior of those students who succeed in one or several AL activities, but only slightly cover unsuccessful participants. Nevertheless, weak students also have different learning styles and might follow their own roads to success that depend on their particular strength, whether in the long-term or the short-term activity.

In order to examine the sources of failures in AL, four groups of learners were compared in terms of individual engagement and success in learning. Analysis of these groups demonstrates that the student-centered approach is not a universally successful method of teaching and learning when it comes to students of different levels and backgrounds. A number of other conditions are necessary for success, namely, working in small groups, taking account of learners' ability to understand, individual instruction methods, etc. Only strong students benefit from using AL in its entirety. Others largely require direct, teacher-centered instruction instead of AL or in addition to AL, which could be helped along by various exercises or assignments, be they mandatory or not, to guide in this process. Therefore, the need for a rigorous and systematic orientation of learners must form an integral part of the university staff activity aiming to provide a clear understanding of the learning destination, and the knowledge where he/she is now so that a student can take steps that lead in the right direction.

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