Technique of active online training: lessons learnt from EngiMath project

A. Uukkivi, E. Safiulina, O. Labanova, M. Latõnina[1]
V. Bocanet, C. Feniser, F. Serdean[2]
A.P. Lopes,F. Soares[3]
K. Brown, G. Kelly, E. Martin[4]
A. Cellmer, J. Cymernan, Sushch, I. Kierkosz[5]
J. Bilbao, E. Bravo, O. Garcia, C. Varela, C. Rebollar[6]

[1] TTK University of Applied Sciences, Pärnu mnt 62, 10135 Tallinn, Estonia
[2] Technical University of Cluj-Napoca, Memorandum Street 28, 400114 Cluj-Napoca, Romania
[3] Polytechnic Institute of Porto, Rua dr Roberto Frias 712, 4200 465 Porto, Portugal
[4] Letterkenny Institute of Technology, Port Road, Letterkenny, County Donegal F92 FC93, Ireland 6539078V
[5] The Koszalin University of Technology, Śniadeckich 2, 75453 Koszalin, Poland
[6] University of the Basque Country, Barrio Sarriena s/n, 48940 Leioa, Bizkaia, Spain
uukkivi@tktk.ee

Abstract. The goal of this paper is to introduce a technique of creating self-tests that has allowed to actively incorporate university students into the learning process. The study was conducted within the framework of the Erasmus + Project EngiMath. Partners' peer reviews, the survey results and the students' comments in forums and test results were used to conduct the research. The students' overall satisfaction was in a high level. However, opportunities for some technical improvement has been emerged like the formulation of the tasks needs to be very clear and the time required to perform the tests must be limited. The following conclusions can be drawn from the study. The use of self-tests at all stages of training has intensified the assimilation of the material, i.e. increased understanding of theoretical material and developed computational skills. By completing a series of such assignments on each topic of the course, students had mastered the methodology of studying the topic and mastered specific teaching material on this topic. Feedback made, taking into account typical errors, has allowed the students to analyse their knowledge. A large number of variations for such tasks has allowed students to be involved in the process of active independent and individualized self-study.

Keywords: Online Self-Assessment, Teaching of Mathematics, Test Design.

1 Introduction

As far back as 1968, it was shown (Bloom, 1968) that the quality of knowledge acquired by students directly depends on the amount of time personally spent by students on independent assimilation of material. Later a learning approach called Learning for Mastery (LFM) was developed (Bloom, 1984). Accordingly to LFM students regularly test using formative tests, and their are required to demonstrate a correct answer to 90% of the test tasks, that is, demonstrate "skill "/"mastery". When the student fails to master, further teaching and testing are repeated, if necessary, several times. Students believe that self-tests are a useful learning strategy (Kulik, Kulik, and Bangert, 1984).

Various adapted versions of this system are now being actively implemented both in countries with developed higher and secondary schools, and in developing countries (Anderson and Block, 1987). In Estonia, this strategy (learning approach) presented in the works of E. Krull (Krull, 1991). The development of tasks for self-monitoring in all studied modules is one of the stages of the system of complete assimilation. At the same time, organizing assignments for students who are potentially at different levels of knowledge is difficult. Online opportunities come to the rescue. In Pelkola, Rasila and Sangwin (2017) and Pelkola, Rasila and Sangwin (2018) Bloom's Learning for Mastery model was adapted using online exercices and online formative tests. Self-assessment through the online exercises with feedback plays an important role in getting students to reflect on their own learning and to self-manage their learning process, which can increase their autonomy and intrinsic motivation (Ibabe & Jauregizar, 2010). According to Sumantri and Satriani (2016), a student's higher level of independence affects the results of that student's mathematics learning positively.

The current study describes the technique of development of self-tests accordingly to the Bloom's mastery learning approach that has allowed to actively incorporate university students into the learning process.

2 Background

2.1 Project and course overview

The role of technology is to facilitate teaching and to promote learning in an authentic situational manner and this role is now central to support of "student-centred" learning. Prompt feedback provides reinforcement, guidance, confirmation of learning and encouragement; all is necessary to foster and promote an active learning ethos. To implement this, the EngiMath – Mathematics online learning model in Engineering education – project was launched.

EngiMath project started in 2018. The project includes teachers from the TTK University of Applied Sciences/TTK UAS from Estonia (project coordinator), the Letterkenny Institute of Technology/LYIT from Ireland, the Polytechnic Institute of Porto/P.PORTO from Portugal, the University of the Basque Country/UPV/EHU from Spain, the Technical University of Cluj-Napoca/UTC from Romania and the Koszalin University of Technology/PK TUK from Poland. One of the main outputs

of this project is an 3 ECTS on-line course on engineering mathematics, which is created in the Moodle TTK UAS learning environment. The main goal of this course is to develop basic and structured knowledge and practical skills in the mathematical sub-area of matrices, determinants and linear equations systems related to engineering.

After identifying common problems that exist for students of the first year of study at the universities of partner countries, and conducting a comparative analysis of their curriculum, a common core of mathematical topics was identified (Brown et al., 2019). Using the common core agreement, the development of 22 lessons with theoretical, practical and assessment materials and activities started (Soares et al., 2019).

Based on the knowledge gained, in the frame of Erasmus+ project EngiMath a huge question bank has been developed for the online engineering mathematics course. Special attention was paid to the development of STACK (System for Teaching and Assessment using a Computer algebra Kernel) questions and step-by-step teaching tasks that give students a certain logical sequence of mental actions that must be performed to solve the problem (Pelkola, Rasila and Sangwin, 2017).

2.2 Tests and Questions

The Estonian partner using many years of experience (Labanova et al., 2020) started to create practical activities in the form of tests. A corresponding practice test has been created for each theory lesson, i.e 22 practical tests have been created. Each test consists of 8-12 questions, depending on the theme and the order of questions followed from lightest to complex principle. Self-tests are characterized by a large number of questions related to specific topics in order to build knowledge and skills. A detailed description of the questions and creation techniques are provided in section 3.

These tests focus on issues with learning difficulties and common mistakes, so the point system is not used. Since the test is educational in nature, the number of attempts to solve it is unlimited, moreover, the duration of the tests is not limited. This will give students the opportunity to analyze the mistakes made, assess the depth of knowledge gained, identify gaps in learning, more carefully repeat and study the training material, and then pass a new exam. On the other hand, an unlimited time of attempts allows students with different levels of learning new material to pass testing at an individual pace. Tests can be conducted by students in a suitable place and time in the Moodle environment, that is, they can be used regardless of the specific computer and are not related to special software and a more common web browser should be enough.

Based on the objectives of the tests for each lesson, a testing model was compiled: a technological matrix containing competencies selected for testing. For each competency, questions were created. For variability each of these questions has in average 10 versions. Some versions of the question are created using the STACK question type, which generates the question with updated source data when the test is run.

The question bank consists of 200 questions. So, in total considering, the number of questions' versions there are at least 2000 items in question bank. There are 50 close-ended type questions and 150 open-ended type questions. Exhaustive feedback has been provided for each question.

When writing the questions, authors followed the guidelines for creating tests (Beilmann, 2020, Ruul, 2008, APSTest ver. 2.0 user guide, 2000). An important point in creating test questions is to build the question itself. The question phrase expresses the question that is asked of the student or the task that the respondent is required to perform. Regardless of the choice of the test when formulating a question mark, care is taken to ensure that the text of the question is short, clearly worded, simple and unambiguous (see Fig. 1). Authors observed that the text does not contain terms that do not appear in theory. It was checked that the terms in the text of the question were the same as in the theory, so that there was no conflict between the theory and the concepts in the questions. The wording of the question took into account that the students have different pre-school backgrounds, so complex mathematical constructions were avoided when formulating the questions.

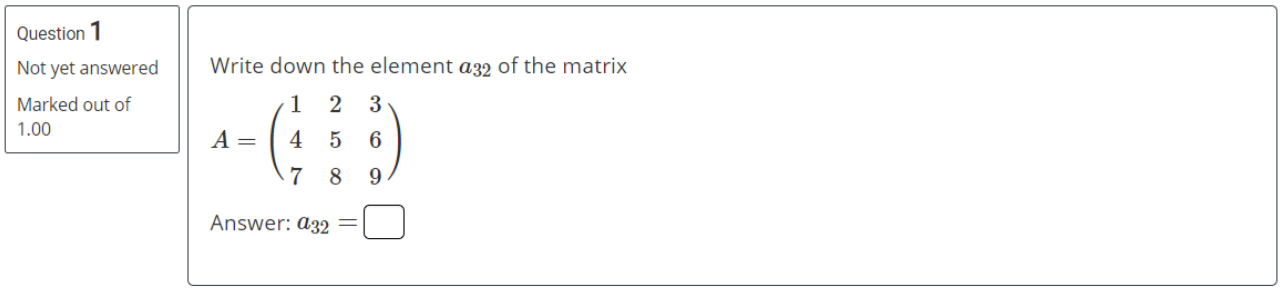

Fig. 1. Short and simple question

When compiling a test question, it is recommended to ask only one question or statement (Beilmann, 2020), which was applied when creating tests with authors. On one occasion this rule was violated and asked two logically related questions in one question (see Fig. 2). It must be acknowledged that this issue can be simplified by dividing it into two shorter issues.

Further are described the types of questions, used in the practise tests. For each question, a type was selected. The authors also substantiate why this or that type of question was used. Both close-ended and open-ended question types were used to create the tests, with 50 and 150 items, respectively.

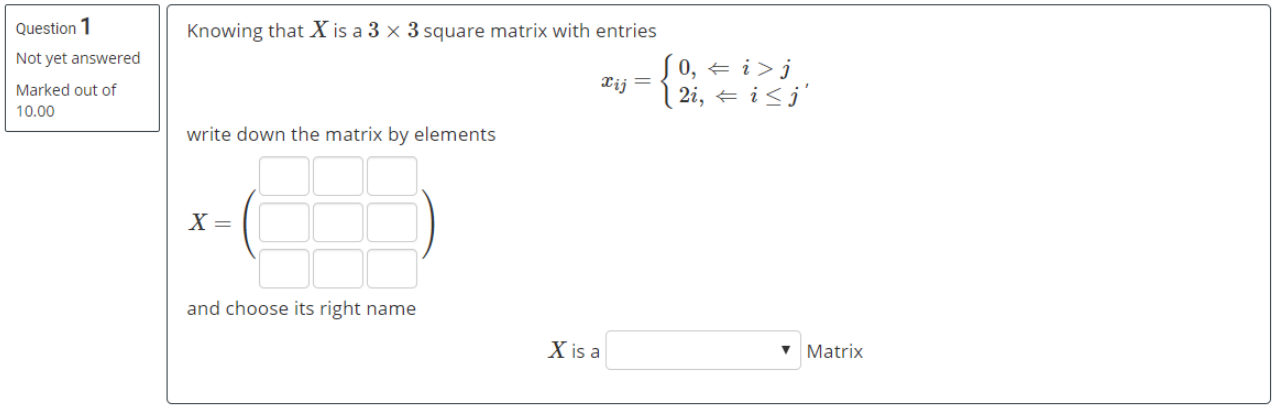

Fig. 2. Question with two short issues

The following types of closed-ended questions were use: Multiple Choice, Word Select, Matching, Drug and Drop and True/False.

When compiling the Multiple Choice and Word Select questions, diagnostic goals were followed, that is, incorrect answers were formulated on the basis of "close to right". The questions were compiled taking into account expected and typical errors. Although Word Select and Multiple Choice have an similar idea (the student must choose an answer from the list), the authors used these questions purposefully. Namely, Word Select was used to achieve that the question would not be visually "heavy", to avoid long list of possible answers one was visually compact. (see Fig. 3)

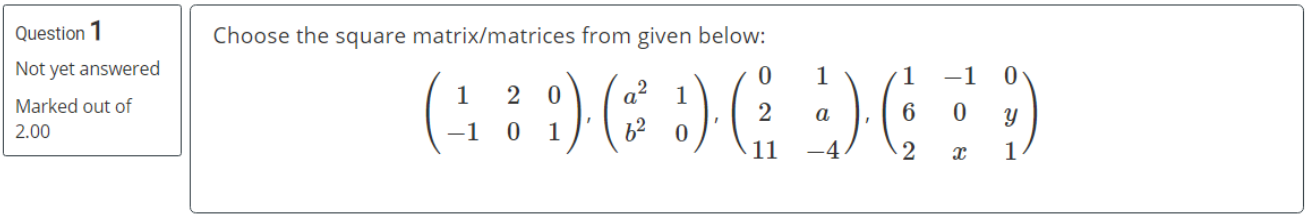

Fig. 3. Word Select type of question

Matching and Drag and Drop question types were used to assess homogenous knowledge. Also in such issues there is important to train remembering factual information (see Fig. 4).

Fig. 4. Matching type of question

True/False questions was used to get quick feedback of student's understanding of theoretical material, to measure the ability to recognize the correct statement, the correct definition of a term, the correct formulation of a principle. When compiling the alternative questions, we ensured that both alternatives were presented equally (see Fig.5).

Fig. 5. Use of True/False type of question

Open-ended questions were used to avoid a random answer and students could demonstrate their understanding. For such purpose, questions Close Embedded, GapFill and STACK were used. When compiling the gap text, we took into account that with these types of questions, the student can enter either the final result (see Fig. 1) or some part of the solution (see Fig. 2) or step by step the whole solution (see Fig. 8). To be able to answer the questions posed in step by step question and solve the problem student should study the relevant sections of the discipline. In addition, the student

must remember the previously studied concepts of this topic.

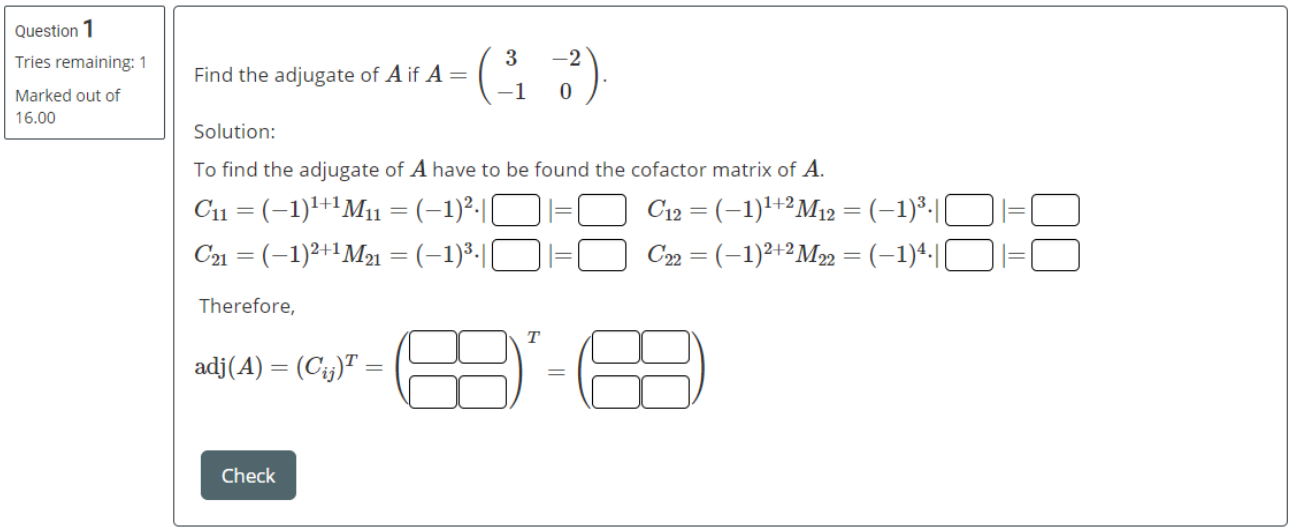

Fig. 8. Step-by-step question using Gap Fill type

STACK (Pelkola, Rasila and Sangwin, 2017) type of question was chosen because of the possibility of generating initial data and generating feedback for each question (see Fig. 9)

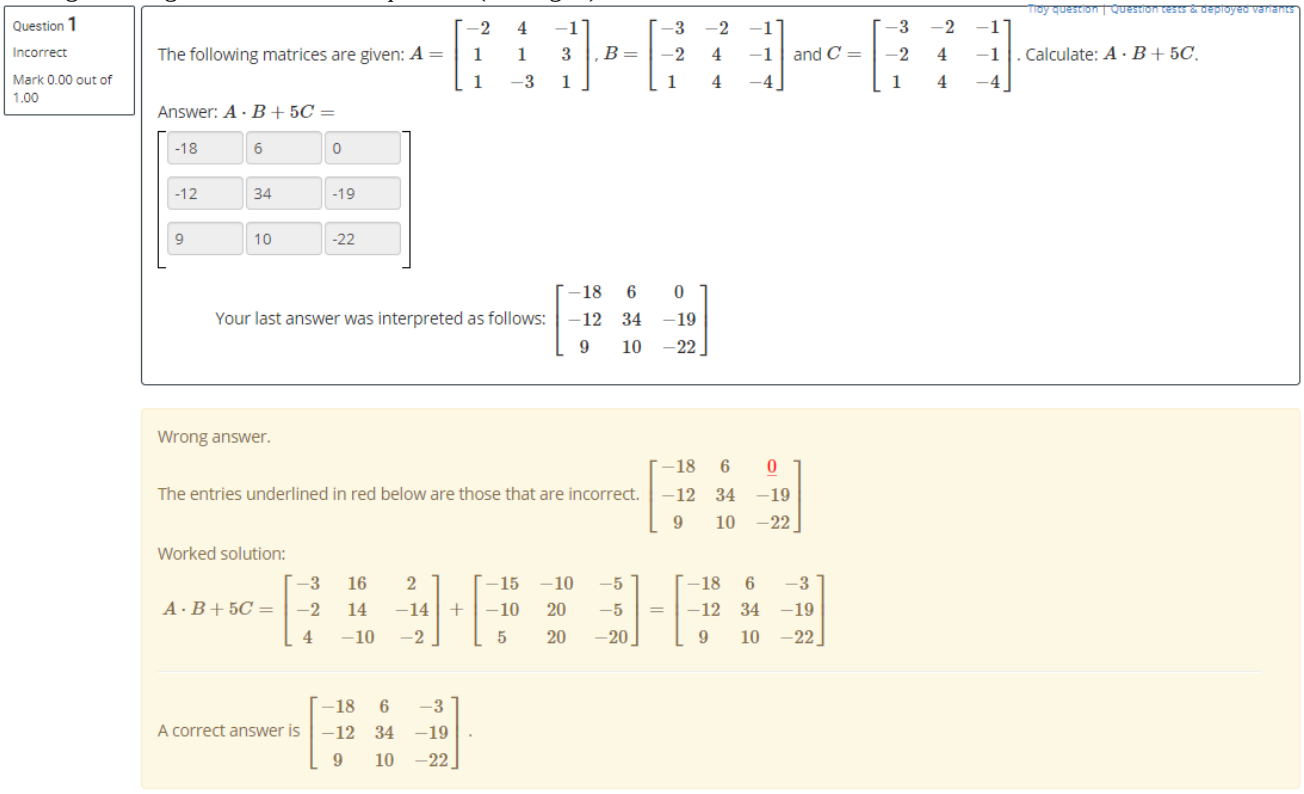

Fig. 9. Use of STACK type of question with feedback

Unfortunately, open-ended assignments often generate several correct, but logically disproportionate answers, which is undesirable from the point of view of an unambiguous assessment and technological control. To prevent unwanted interpretations of students, we use smyslovye constraints, such as “calculate to the nearest hundredth” or technical hint such as “abs (x)”, “sqrt (x)” and also tooltips adding them to questions using HTML code in Moodle.

3 Approach

Collaborative peer review, approbation though the pilot and a survey method was selected for conducting the study.

3.1 Collaborative Peer Review

A review of all question for content quality and clarity by external subject-matter experts (collaborative peer review) is a necessary step in the test development process (Downing and Haladyna 2006). The analysis of expert assessments was carried out by the brainstorming method (Osborn, 1953) and suggested that the experts fill out a joint document in which a comprehensive analysis (linguistic, didactic) of test questions is made and possible ways to improve the situation are identified.

Despite its outward simplicity and accessibility, brainstorming is a very effective technology for generating ideas (Putman and Paulus, 2004). The main disadvantage of this method is the impossibility of deep penetration into the subject of discussion by all participants involved in it. In order to overcome this shortcoming, discussion organizers need to focus on the selection of discussion participants and the composition of the analysis group (Sutton and Hargadon, 1996). In our case, colleagues and educational institutions of partner countries acted as experts, which allowed us to avoid a superficial study of the material. Constant comparative analysis was used to analyze the data.

3.2 Approbation

To determine the quality and effectiveness of the tests, approbation of Lessons 1-7 was conducted in which 40 first-year Building Construction and Facilities Management daytime students of the TTK University of Applied Sciences took part in 2020 alongside students from other countries. This study is based only on the feedback of Estonian students, as they were chosen to give the most thorough feedback on the self-tests. Content comparative analysis was also used to analyze these data.

Since in mastery learning, there is no concept of marks as such, but simply "passed / not passed", either students have already mastered the field or not (McAlpine, 2002), therefore, the analysis of the test questions was carried out by calculating the difficulty index and the average test time. Although the time of the tests was not limited, it was suggested that two hours was enough, so attempts lasting more than two hours to calculate the average duration were not taken into account. Mathematical and statistical processing of test results was carried out using the MS EXCEL package. For difficulty index calculating a dichotomous grading scale was used: for each test a matrix was formed (student serial number x control questions) with repeated attempts and entries 0 (incorrect or partially correct answer) and 1 (correct answer).

Each lesson includes a forum to exchange ideas and problems by posting comments. In addition, the students' comments in forums were analysed.

3.3 Students survey

At the end of approbation an online questionnaire was sent to students to assess their perception of the online materials. Students were asked to provide their age and study program and to answer questions relating to theory, practice, and assessment materials. The questions were measured on Likert scales of varying lengths (either 6 or 7 points depending on the question). Some scales had an even number of options to force the respondent to think better about their response. Others had an odd number of options as they were ranging from too little to too much, the middle value being the optimal. For six-point scales, the first two values (0, 1) were considered as reflecting a low level of agreement, the next (3, 4) were a moderate level, and the last two (4, 5) a high level of agreement. Open ended questions were also asked. The questionnaire was written in Estonian and was disseminated by using Google Forms in February 2020.

Twenty-four students answered the questionnaire, all in the 18 and 29 age group. Half of the students were enrolled in the Facilities Management study program while the other half in Building Construction. There was a wide range of experience with the material prior to the course. Most students (46%) had little or no prior experience, while 21% said that they had a lot of experience. The data was analyzed from a descriptive standpoint.

4 Results

4.1 Partners' peer review

There were 55 comments from the experts in the common document. In the collected comments and suggestions of experts, 6 main categories appeared:

- Guide for the questions name;
- Test setup;
- Adequacy of the test;
- Comprehensibility of the question;
- Correctness of the question;
- Question feedback.

Guide for the questions - comments on description of the general format of the question name.

Entry 3: *Suggestion – we feel that it is important to distinguish all questions –....– question name begins with section number to distinguish.*

Test Setup - quiz administration settings block with timing, grade, layout, question behaviour and review options.

Entry 18: *Quiz 2 – it does not allow to repeat as in Quiz 1 – we felt this was a plus for formative/practical purposes*

Adequacy of the test means - the content and length of the test is sufficient to test the knowledge, skills, etc. of the given topic.

Entry 5: *Quiz 1 – better to remove last question – …– Unit matrix is not defined at this point*

Comprehensibility of the question - the question is clear, unambiguous

Entry 43: *19.03 and 19.04 We have some difficulty in agreeing with the text in these groups of exercises since there are several solutions for x and y. We propose to change the text to something like:"Without the application of Sarrus' rule or any other computations, point out the values of $$x$$ and $$y$$ that allow us to conclude directly that: "*

Correctness of the question - the question is logical, linguistically and technically correct)

Entry 34: *Please see what happens in some trials – Not every time…We went to html-code and changed "ENG" to "ENG-US" …*

Question feedback - the feedback on the question is correct

Entry 13: *2.2 – questions 02 to 10 – general feedback – insert spaces "A matrix is said to be square if the(SPACE)number of rows(SPACE)is equal to the number of columns"*;

4.2 Results of the approbation

Results of students' forum postings

There were 12 posts in the online course's forums. As a result of forums' posts analysis, three categories appeared: presence of typos, ambiguous formulation and content questions. Usually the posts were provided with a corresponding image of error.

Presence of typos. In the forum posts, students pointed to test questions' places in which typos were made. Typos can be divided into two groups: technical errors and errors made when translating from English into Estonian.

Post 3: "Error in first test: inconsistencies in matrix dimensions."

Ambiguous formulation. In the forum posts, students cited places from test questions in which the question in their opinion was ambiguous.

Post 2: "Confusion of terms? A matrix row is a matrix whose number of rows is equal to the number of columns."

Content's questions. Students used forums to ask the teacher for advice on the correct decision. They also brought their solutions in the forum in order to receive feedback from the teacher.

Post 7: "Question about the calculation procedure in question/item number 6: is it correct that x = -1? What is the calculation procedure?"

The lecturers of the TTK University of Applied Sciences systematically responded to the posts of the forums, corrected the wording and typos and gave feedback to the project partners if necessary.

Results of tests analysis

The results of the analysis of tests that have passed approbation are presented in the table (Table 1). Question analysis was conducted for each test by computing the difficulty index, using the classical test theory, and test duration. The target range for difficulty index was defined from 20 to 80 and the percentage of items considered too easy (less or equal to 20) or too difficult (more or equal to 80) are calculated. Reliability was not calculated, because the purpose of testing is to increase the level of students' knowledge, i.e., with each new attempt, the number of tasks that students cope with increases.

The total number of questions was 64 (range: 8 – 11 questions per test) and total number of questions with variations was 475 (range: 40 – 90 questions per test), while the number of examinees was 40 (range: 27 – 40 examinees per test). All students attempts were taken into account in compiling the table, each student was allowed to use more then one attempt. Mean difficulty index ranged from 9.11 to 65.96. Easy questions appear in Test 1, Test 2, Test 4, Test 5 and Test 7. Difficult questions appear in Test 3 and Test 6. Average time to pass the test ranged from 3 to 48.

Table 1. Tests analysis.

Criteria	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test7
Number of questions	9	8	9	10	8	11	9
Number of question with variations	90	81	91	80	53	40	40
Number of students	40	40	39	38	37	32	27
Number of attempts	62	59	73	47	46	47	30
Mean difficulty index (%)	13.08	9.11	55.10	38.53	39.67	65.96	37.5
Easy questions (%)	88.90	87.50	0	20	12.5	0	11.11
Difficult questions (%)	0	0	11.11	0	0	45.45	0
Average time (min)	~ 7	~ 3	~ 21	~ 27	~ 23	~ 48	~ 26

4.3 Results of students' survey

Most students (83% for practice and 79% for assessment) considered the practical and assessment material was highly related to what was taught. Most students had no or little difficulties with the theoretical (75%), practice (83%) and assessment materials (79%). The students that did have difficulties found the material as being complicated and that they needed to read it multiple times.

Most students considered that they had either just the right amount of time to complete the practice (42%) and assessment tests (38%) or even too much time (50% for practice and 62% for assessment).

Students considered that all course materials will help with their final exam (83%) but were less convinced that the material will help them in real life. Only slightly more than 30% strongly agreed while about half were moderate in their answer to this question. This opinion was very similar regardless of the type of material used.

More than half the students considered that they had just the right amount of materials (54% to 58% depending on material type) but some considered that there was too much material (38% to 46%). The highest proportion of students that considered that they had too much was for the assessment materials.

Around 55% of students considered all material easy to use while 30% to 40% considered it moderately easy to use. They liked the graphics (58% strongly agreed), didn't consider that there was too much text (63%), found the material intuitive (54%), with a logical flow (63%), easy to navigate (54%), and that it had enough information (88%).

Students were also asked how the course could be improved. Their answers were used to create a word cloud that outlined the frequency of terms used by students. Common words that don't add value, called stopwords (e.g. the, a, at, of, he, she) were removed prior to the analysis. The resulting word cloud is shown in Figure 10. The analysis revealed that students considered it a good idea but also felt the need for more examples and some said that the intervention of a teacher would be helpful.

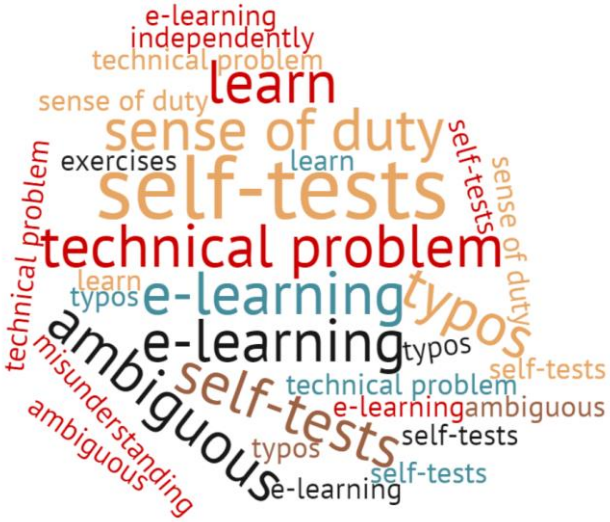

Fig. 10. A word cloud showing students' opinions about self-tests

5 Conclusions

From peer review, in accordance with the experts suggestions outlined above, a system for numbering test questions was developed:

Lesson: <Lesson No. 0> <Name of Lesson>

Question: <Lesson No. 0> <Question No. 0> <Name of Question>

Questions' variants: <Lesson No. 0> <Question No. 0> <q> <Questions variant No. 00>

Due to a peer review and post analysis from the forums questions and tests were redid the confusing. Authors found forums to be a good tool for getting quick feedback from students during passing the tests. The authors conclude that it takes an average student one hour to pass one test. Based on the data shown in Table 1, can be seen that Test 1 and Test 2 turned out to be the least difficult and the time to complete them was also the least. We can conclude that in the future, Yeti 2 test can be unified. The table also shows that Test 3 was the most difficult. When examining the test in more detail and relying on students' feedback, the authors paid attention to the fact that many mathematical symbols were used in this test and this could impede the visual perception of the question as a whole. With further development of the course, it is planned to create tests by difficulty levels (easy, medium, hard).

Feedback from the students shows that the number of self-tests was sufficient to acquire the subject and that the tests are logically structured. However, the formulation of the tasks sometimes raised questions; it needs to be reviewed. The students emphasized that independent learning increases the sense of duty and allows active participation in the learning process.

In the future, it is also planned to study the effect of the number of attempts to pass the test and the time spent on it with the results of control on this topic. Moreover, authors plan to check how the results of self-tests, assessment tests and course assessments are related.

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