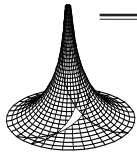

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Teaching
Mathematics and
Computer Science

Gamification in Higher Education

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Abstract. The way of thinking and the way of life of the today's children and teenagers have changed radically. Some of the well-established pedagogical methods that were used for decades have become obsolete. Therefore, we need to look for a new method to approach Generations Z and Alpha. Gamification, which has been known since 2010 and means the use of game elements in other areas of life, offers an opportunity to do so.

In addition to a brief description of gamification, my article shows some possibilities for using it at the university. Furthermore, I investigate the impact of gamification on the student in "Algorithms and Data Structures" university course.

Key words and phrases: gamification, IT education, computational thinking, edutainment, motivation .

MSC Subject Classification: 97P30.

Introduction

Nowadays, the generation gap is widening, making the task of educators increasingly difficult. Most of the teachers belong to Generation X and they got close to the Internet in their adult years. They already have experience but are reluctant to use innovative methods. Today's high school and university students are members of Generation Z and Alpha, who grew up with the availability of the internet from their childhood. For them, the use of smart devices is self-evident. They easily manage the rapid flow of information and often switch between activities during multitasking, which makes it difficult to catch their

attention with traditional frontal methods. The visual display is preferred over long, unstructured texts.

Today's educator society has a big task to do. It is necessary to understand the new language, communication and motivational structure of the net generation, and accept that the culture of receiving and communicating information and of attention has changed. In addition, educational methods must be changed accordingly, as well. The "gamification" of education gives an idea to solve this problem.

Definitions of gamification

Gamification is a fairly new term with many precursors. Researchers have formulated a number of definitions for gamification. In this chapter, the most commonly adopted ones will be reviewed.

Gamification was first defined by Nick Pelling in 2002 as *"Applying game-like accelerated user interface design to make electronic transactions both enjoyable and fast."* (CaptainUp, 2020) Its definition and meaning have undergone many significant developments, with different meanings being introduced into public consciousness.

The most common definition nowadays comes from Deterding (Deterding, Sicart, Nacke, OHara, & Dixon, 2011) in 2011, which says: ***"Gamification is the use of game design elements in non-game contexts"***.

Zichermann and Cunningham expanded their interpretation in 2011, they define gamification (Zichermann & Cunningham, 2011) as *"the process of game-thinking and game mechanics to engage users and solve problems"*.

Kapp further refined this definition in 2012, focusing on the learning support role of gamification. According to Kapp (Kapp, 2012), *"gamification is using game-based mechanics, aesthetics, and game-thinking to engage people, motivate action, promote learning, and solve problems"*.

In 2012, Werbach and Hunter, based on the definition of Deterding, separated game elements from game design techniques, emphasizing that successful gamification is a more complex process than the juxtaposition of some game elements. Their definition (Werbach, 2012) says: *"The use of game elements and game-design techniques in non-game contexts"*.

In 2013, Zichermann reformulated his original definition with the help of Linder, using ideas integrated from loyalty programs. According to the redefined

definition (Zichermann & Cunningham, 2011), gamification is *"implementing design concepts from games, loyalty programs, and behavioral economics to drive user engagement"*.

In 2014, Burke narrows the definition to methods that involve personal interaction with digital devices. According to his definition (Burke, 2014), gamification is *"the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals"*.

All the above definitions are in contrast with the definitions of two Finnish university professors, Kai Huotari and Juho Hamari (2012), who emphasize the experimental nature of gamification rather than its systematic approach. They defined (Huotari & Hamari, 2012) gamification as *"a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation"*.

Development, spread and characterization of gamification

The concept of gamification in the public mind appeared in the 2000s and has become popular since 2010, but its origins can be traced far back.

Fuchs (Németh, 2015) found examples of the use of gamification in the army dating back to early Roman times.

Nowadays, many companies use gamification.

Figure 1. Leaf trees

For instance, Nissan Leaf allows the driver to grow trees by adopting a certain driving style, to make driving more playful. Finer driving saves fuel so your tree grows faster. If the tree is grown, we can start growing another one. (It can be seen in Figure 1.) Sharing results on the Nissan Community Network (Eco Leaderboard) allows us to compete against each other for the safest or greenest driver titles.

Two very important concepts appear in the definitions of gamification: game elements and game mechanisms, which are often called game design techniques. Game elements refer to tools taken from traditional and video games, and game mechanisms to the application of the operating principle.

Of course, tools will only work effectively if the mechanisms of a game are given: a game is voluntary, promising success, transparent and properly delimited (providing proper time).

The "out-of-game context" term in the definition implies that the purpose of the game is different from that of gamification. The biggest difference between

game and gamification is that a game is an activity providing entertainment or amusement whereas the purpose of gamification is to do something to achieve a predefined goal in real life

Gamifying education

How can you gamify education in the classroom?

Gamification in the process of teaching

A lesson may be more interesting if we have our students compete or we use role-play instead of frontal instruction. The key to applying these methods is that students do not only listen but actively participate in the lesson.

However, a safer way to do this is to engage students into the class with free software. By using such apps, students become more motivated, interactivity-enhanced, and receive feedback on understanding the curriculum much faster and more accurately. However, these tools do not only support group work, but can also be very important in the individual learning experience.

Gamification in grading

Instead of grading, which can trigger self-esteem issues and increase students' stress, a scoring method which is associated with the name of Tibor Prievara, is already widespread. He suggests that we divide the teaching process into certain units, such as monthly periods. During the units, students can earn points for their compulsory and non-compulsory assignments (i.e. homework, presentation and test). The points are converted into grades at the end of the period so they receive a grade each month.

Many papers (Froman & Damsa, 2016) report the benefits of the scoring method from the perspective of both students and teachers. Students were more motivated and active during the lesson, as a result of which they were more aware of their own activities and more aware of their goals. Teachers received more frequent and valuable feedback, giving them a better insight into the degree of learning and the needs of students. Furthermore, using points allows educators to align levels with skills and highlight the inherent value of education.

One of the great benefits of point systems is that they focus primarily on development and accumulation. While grade-based evaluation calculates averages, points give you an opportunity to experience a sense of growth and progress. In

such an environment, the student will not feel a failure due to a worse grade but will be closer to the next level.

What can you use in teaching?

By using gamification, we take over elements of the gaming system that can help us motivate our students, reduce their stress level, as well as help them become more independent and truly participate in the decisions regarding learning. Gergely Nádori (Nádori, 2012) mentions the following elements:

- Autonomy
- Antidote to boredom
- Goals
- Success and failure
- Immediate feedback

Appearance of gamification in "Algorithms and Data Structures" I and II university courses

Due to the theoretical nature of the subject and the early appearance of Algorithms and Data Structures in the curriculum, I found it necessary to use the possibilities of gamification in my practical classes. I also discussed the changes with the students in the form of an anonymous questionnaire, which was completed by 35 students (out of 42 I had been able to address). This participation far exceeded the results I had expected: i.e. 83% of the students participated voluntarily despite the fact that their reward was only 2 points. All of these numbers show that students also see the potential of gamifying the course.

As an initial step, I introduced a points system in the semester, i.e. it is not only the results of the tests that matter in the evaluation.

The points system I applied is as follows. Students are required to write two tests, for 60 points each. On both tests, the mandatory minimum is 20 points. In addition, they are given homework after every lesson, the solution of which is not mandatory, but an extra point-scoring opportunity. They can earn a total of 20 extra points from homework. In addition, they are given programming tasks from which they can similarly earn a maximum of 20 points. I also award points to those who do more serious research on a topic related to the curriculum and share it with us in some way. Based on this, I calculate their end-of-semester grade

from the total of their points. If someone does not reach the required minimum on tests, they have to retake them, i.e. failed tests cannot be compensated for by other scores by any other scoring.

In addition, I created a playful application for the lesson, which I assigned as homework, available on my website. (Pusztai, 2018). If the students completed the task successfully, they received a point and 5 minutes of "opportunity". (I doubled the mentioned rewards for the more difficult tasks.) The "5-minute opportunity" can be used for compensating for delays of the lesson, a total absence from a lesson, or using some extra time to spend on tests. So it can be said that their rewards were quite modest, yet a lot of students dealt with it. Students had a positive opinion of the scoring system; only two students (6 %) preferred the traditional grade-based evaluation method.

However, the "opportunities" reward system was not as successful as scoring. Less than 2/3 of the students thought it was good (55%) to reward them with opportunities, while the rest (45%) would have stayed with just the points.

This opinion of the students was also reflected in the evaluation of the reward methods. While 92% liked the "points" reward mode, only 38% viewed the idea of "getting more time for the test" favourably, and only 32% of students were attracted to the opportunity to "absence from class". (It can be seen in Figure 2.) Students' opinion about the homework applications was clearly positive, with a high degree of participation (there was an app development task that was solved by more than 65% of the students) and satisfaction (the average of apps receive well over 4, and everyone except one or two students found it helpful.) Although it was not mandatory to write reviews about the apps, I did receive many feedbacks, (more than I thought). Some of these were as follows: *"Useful and easy to learn with." "Very good, so I noticed that I have shortcomings." "Summarizes the essence of what you need to know; I find it very useful and cool." "It is creative and helps a lot to put the acquired knowledge into practice : D"*

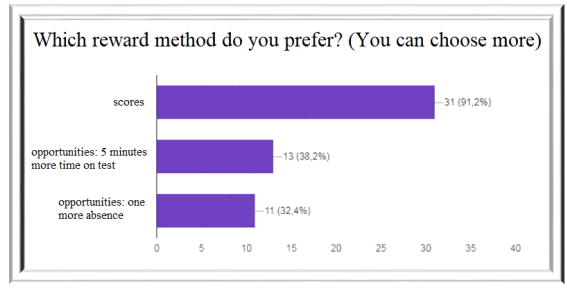


Figure 2. Students' opinion on reward methods

Based on the evaluation of the questionnaire and the high participation, it can be said that the students clearly liked the gamification of the course.

In addition to the gamification of the course, I made the materials that complement the lesson available to the students on my website. Some of these additional materials are Youtube videos or animations available on the Internet, which explain the operation of an algorithm, but of course, there are also self-created materials in the collection.

Animations and Visualizations of Algorithms

The website www.algoanim.ide.sk contains animations and visualizations of several algorithms and data structures. I borrowed the animation of Breadth First Search, Depth First Search and Dijkstra's algorithm from there.(Vegh & Udvaros, 2020) (Vegh, 2016) (Vegh & Stoffova, 2017)

Matching Pairs for practicing AVL tree operations

To practice the operations of AVL trees, I created a memory game in LearningApp Most of the pairs contain a *Tree before and after rotation*(Figure 3a). The other part of the pair contains *theoretical concepts and explanations* that will be necessary for the exam. Examples of such pairs are the definition of Search Tree or AVL Tree, the determination of the height of AVL Tree, the textual description of AVL Tree (Figure 3b), and the relationship and difference between AVL Tree and Search Tree (Figure 3c). I tried to show as many images as possible, thus giving an example and thereby facilitating the visualization of the theoretical curriculum.

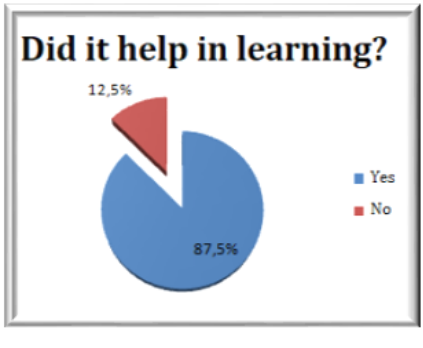
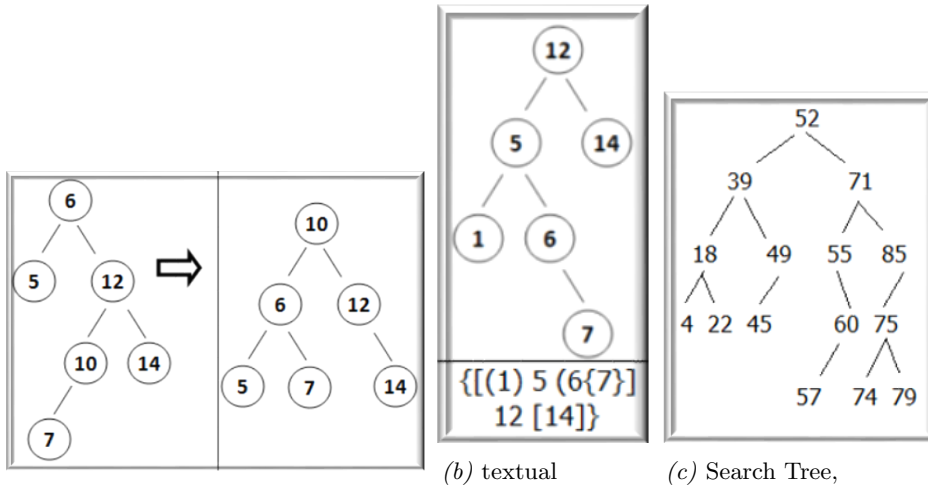


Figure 4. Students' opinion on the app

Students' participation in this task was much higher than in solving an average optional task. Of the 49 students surveyed, 21 dealt with the task (43%) and 20 succeeded. The online questionnaire was filled in by 24 students, who evaluated gamification as good (4.375 on a 5-grade scale), and it was found useful by 87.5% (It can be seen in Figure 4.) This is the task that received the most textual opinions, which were very useful to me, as they included a constructive suggestion. Here are some examples of textual opinions: *"Very good and inspiring! All at once I found*



(a) (++,-) rotation *(b)* textual description *(c)* Search Tree, but not AVL Tree

Figure 3. AVL Tree

myself drawing my 10th AVL tree in my exercise book. I managed to practice the lesson so easily that I almost forgot that I was studying.", "You can really practice the stuff with games; I really like this method: D", "I really liked that it didn?t move on and the puzzle showed what was on it, so we could think about it all way long.", "We had to scroll a lot and it made the task more difficult and less enjoyable. Perhaps it could be split into several smaller (3x3, 4x4) tasks. The idea is to have a memory game that I like."

Pairing task for practicing minimum spanning trees

To deepen the topic of minimum spanning trees, I created a "drag & drop" matching exercise for a HotPotatoes. The task includes 7 images and an appended definition. These images illustrate the concepts formulated in the lesson (e.g. The Blue/Red Edge - coloring rules), algorithms (Prim, Kruskal, Path Compression), and data structures for Kruskal (e.g. Disjoint Union/Find), thus explaining and deepening students' understanding the lesson (Figure 5 shows the solution of the exercise.)

The task was solved by 15 out of 49 (31%), which is a high degree of participation considering that the assignment was in the middle of the semester. The questionnaire was completed by only 7 students, who gave an average score of

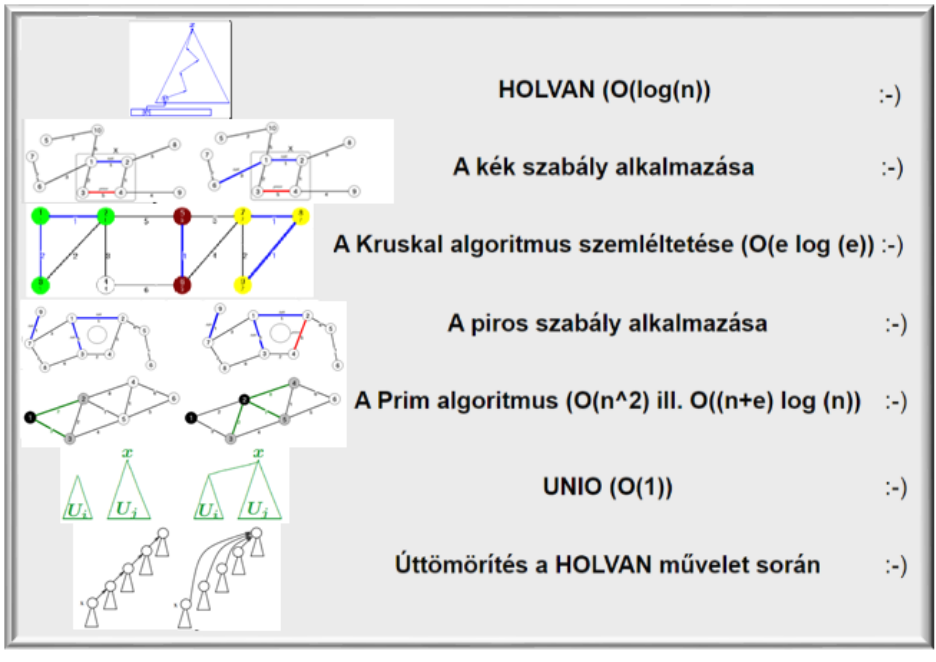


Figure 5. The solution of task

4.29, and every student stated that the app helped them learn. For this task, I received few textual opinions, one of which read, *"The task helped me comprehend and revise the material of the lesson".*

Assignment to images using Dijkstra's algorithm and Bellman-Ford algorithm

Applying an algorithm is one of the most difficult types of tasks, as it is not enough to learn the lessons (e.g. algorithms in this case), but it is also necessary to understand, i.e. to notice the deviation from the general task and adopt it to the specific task. This is why students do not like this type of task; many do not even try to solve it during the examination. However, a programmer uses this kind of knowledge the most in his or her work, so I think it is important to become used to these types of tasks. That is why I also created two "Matching pairs on images" type tasks in Learningapps, one using Dijkstra's algorithm and the other using Bellman-Ford algorithm.

The text of the *"Widest Path Problem"* (Figure 6) created to practice the Dijkstra algorithm is as follows: *"Given a map of a road network, where for each section of the road, we know the maximum width of trucks that can travel along it. Give us an algorithm that determines the maximum width of a truck that can get from A to B."* When solving the task, we need to think about what we need to change compared to the general task:

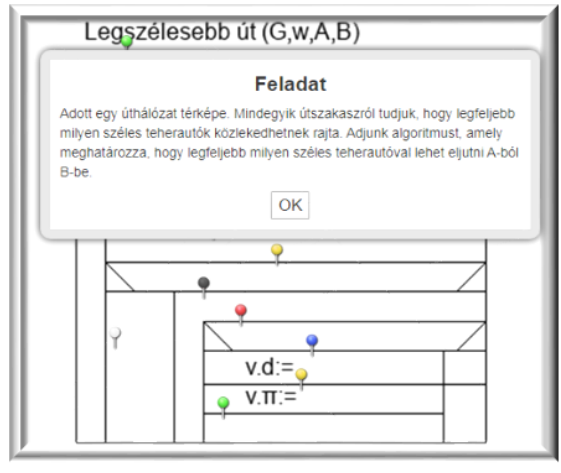


Figure 6. Widest Path Problem initial screen

- Since we are searching for the widest path, a different initial value must be chosen for initialization, (i.e., u.d = 0 instead of u.d = ∞ and s.d = ∞ instead of s.d = 0) because we start from the narrowest path and then expand it.
- In addition, we should also change the extension (i.e. v.d < (min (u.d, w (u, v)) instead of v.d > u.d + w (u, v)).
- You do not have to get to every point; it is enough to get to B. Thus, the algorithm can terminate if B is taken out of the priority queue. (We introduce a logical variable that becomes true with the exception of B. The looping condition is also supplemented by monitoring the variable.)

In the task created to practice the Bellman-Ford algorithm (Figure 7), the goal was to convert he general representation into a specific data structure: *"Write a Queue-based Bellman-Ford algorithm for the case where the graph is represented by adjacency list!"*

During the game, the task and an almost blank stuctogram with different colored place markers appear on the initial image. (It is similar to Figure 6, which shows Dijkstra's initial image.) The students' task is to select and insert the appropriate pair by clicking on the sticks. By scrolling through all the place markers (or if you want to stop the task), you can check your solution by clicking on the checkmark in the blue circle in the bottom right corner of the screen. The correct solutions are given on a green background, while the incorrect ones are given on a red background. (Figure 7 Bellman-Ford)

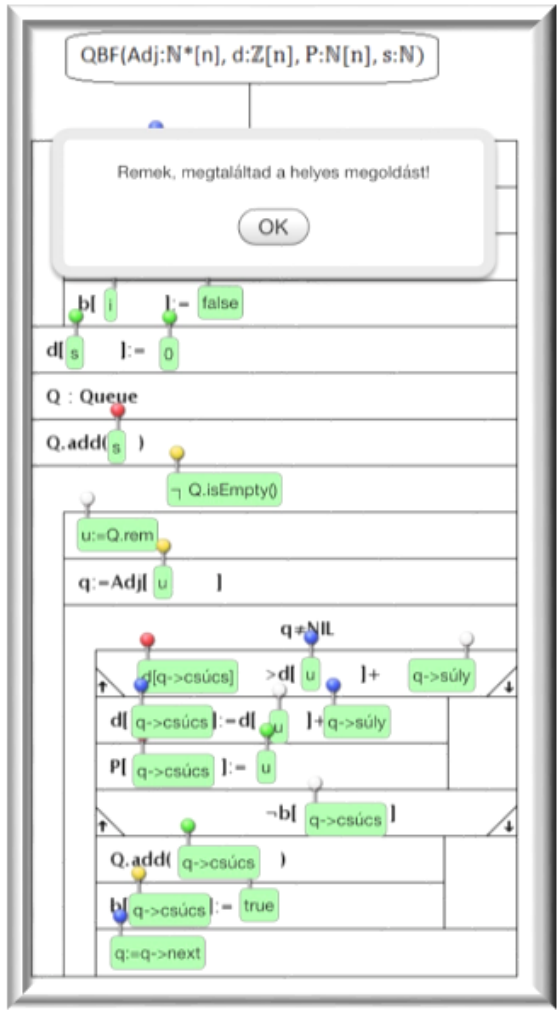


Figure 7. QBF solved task screen

Students' participation in the task is fully in line with my statement, i.e. this is the most difficult type of task. While the task had 60 views, only 18 out of 49 students attempted to solve it, with 15 being successful The Bellman-Ford algorithm had a similar ratio of 11 out of 49 students trying to solve it, 9 of whom did succeed, while the task had 37 views. Based on the data, two conclusions can be drawn: there was at leastone student who ran the task more than once, and there were probably students who looked at the task but found it too difficult and, therefore, did not deal with it.

The online questionnaire for the first task was completed by 14 students, rated at an average of 4.14, and was found to be useful by 86%. The second task was rated by only 3 students at an average of 4.33 and everyone found it useful.

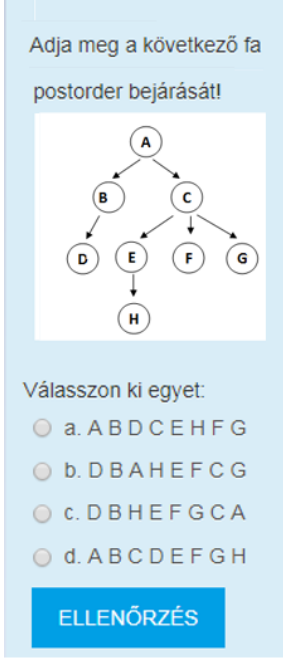
Moodle tests to deepen knowledge about trees

To practice general trees, I created two Moodle tests. The first one (named AA_3) consisted of 6 different types of tasks. Two questions with embedded answers asked about the height of the AVL tree and the time of its main operations (Figure 8c), and there were two multiple-choice questions about the pre- and post-order traversals of the general tree (Figure 8a). In addition, there was a matching exercise that asked for ways of representing the general tree, as well as a short answer exercise about the textual representation of a general tree. A total of 2 points could be obtained for a perfect solution to the test.

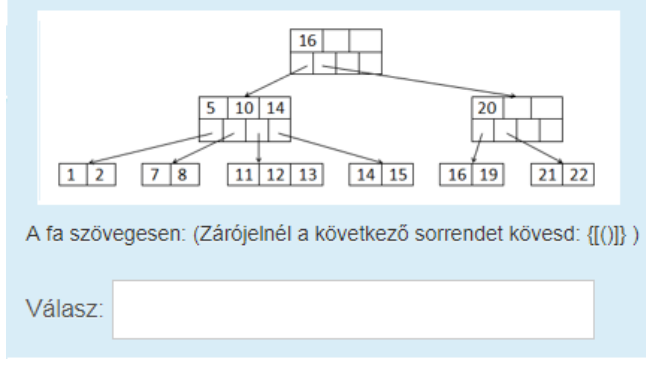
The other moodle test (called AA_4) consisted of 10 questions on the topic of the B+ tree. A short answer exercise dealt with the representation of the B+ tree (Figure 8b), two multiple-choice questions were about the operations of the B+ tree (search, insert), and 7 true-false statements were to deepen the knowledge acquired about the B+ tree. The solution to this test was worth 1 point.

Students' participation and their opinion of the task was shocking to me. Since these tests were the least spectacular and the least playful ones during the semester, I expected them to be the least popular ones as well as the fewest students to deal with it. In contrast, students felt differently, and student participation in these tasks was also exceptionally high, with the first test being completed at 32 out of 49 (65%) and the second test at 34 (69%). Since my goal was not examination, but to deepen their knowledge, students were allowed to solve the tests any number of times. One of the benefits of Moodle is the automatic logging of tasks, so I was surprised to see that there were a total of 48 attempts for the first test and 77 attempts for the second one. (This averages 1.5 and 2.26 trials per person, respectively.) (Figure 9)

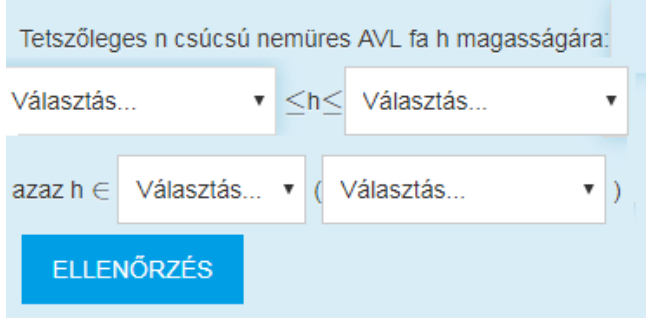
The questionnaire for the first task was completed by 9 and the questionnaire for the second test by 8. Although these are lower participation rates than for the others, this is due to the fact that towards the end of the semester the enthusiasm of the students decreases and the number of other tasks to be submitted increase. Students rated the first test at an average of 4.44 and the second one at an average of 4.375. Both tasks were found to be 100% useful. There were a few textual opinions on these tasks, one of which reads: *"I liked it because I had to*



(a) Multiple-choice question: postorder traversal of the general tree



(b) Short answer exercise: the representation of the B+ tree



(c) Task with embedded answers: the operation time of the height of the AVL tree.

Figure 8. Moodle tests

review today's material. It's also good that there was no time limit on the Moodle test, so it's much much calmer."

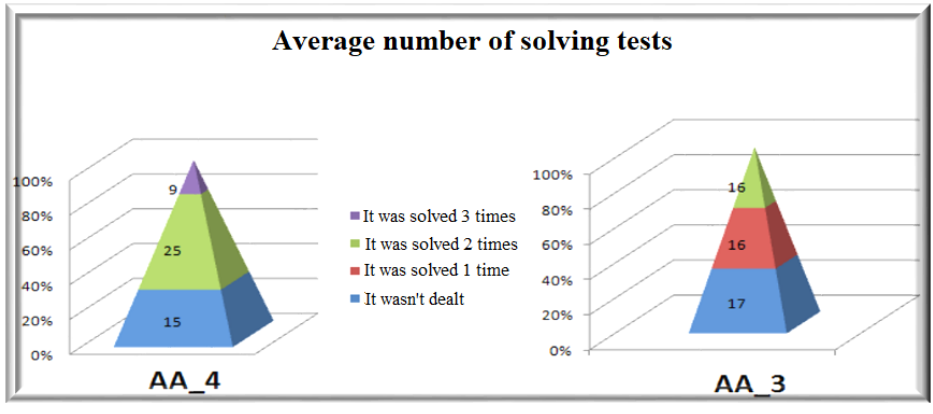


Figure 9. How many times have students tried to solve each moodle test?

Group matching task to practice "Edge Classification of a directed graph after a Depth-First Search"

To practice edge classification and the properties of each class, I created a group matching game in LearningApps. After a depth-first search, the edges of the directed graph are classified into four classes: tree edge, back edge, forward edge and cross edge. At the beginning of the game, these four groups appear in different colors (Figure 10). We will have each definition in the middle, which we need to drag into the right group. If you run out of cards (or if you want to stop playing), you can check the correct solution by clicking on the checkmark in the blue circle in the bottom right corner of the screen. The correct solutions are given a green frame while the incorrect ones are given a red frame (Figure 11).

Figure 10. Start of Group matching game

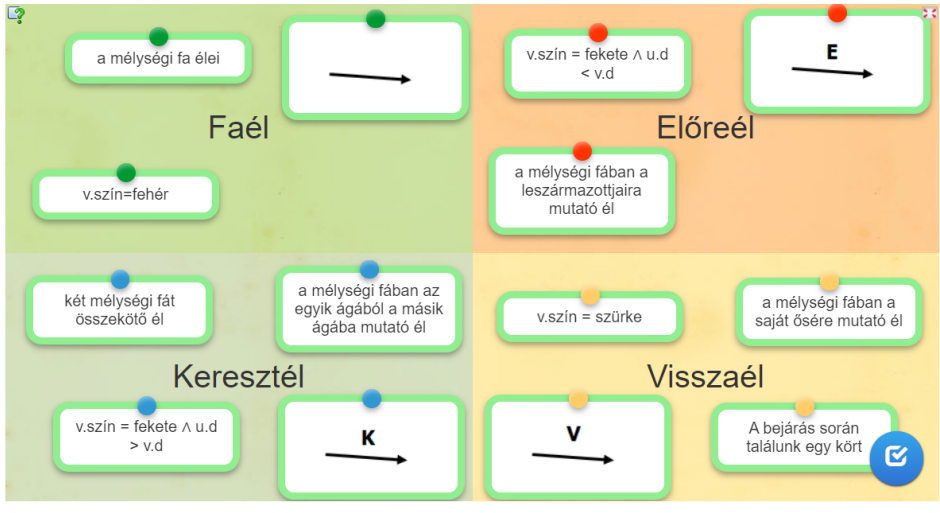


Figure 11. End of Group matching game

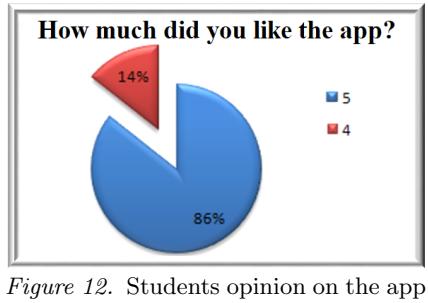


Figure 12. Students opinion on the app

As this assignment was published towards the end of the semester, the enthusiasm of the students had waned, so only 16 people solved it (33% participation). However, 14 students were willing to give their comments, as well. Students liked this application the most, which is shown by its high rating (4.86 on average) (Figure 12). In addition, they claimed that it helped everyone to learn, and it also received 6 positive textual opinions. Some of these are as follows: *"Very creative game; I liked it", "So far I've liked this game the most!", "It was nice and colorful; my girlfriend liked it, too.", "It was great for preparing for the exam!".*

Quizlet set to practice asymptotics

In the topic of asymptotics, I created a Quizlet set for deepening students' knowledge. Most of the pairs consist of a *function* and *its asymptotically sharp bound*, but some pairs include *a sort* and *its average time complexity*. The Quizlet generates 7 different types of tasks from our cards. (Figure 13 shows the match type task in the Quizlet.)

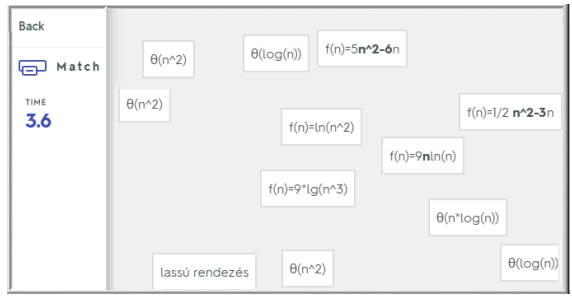
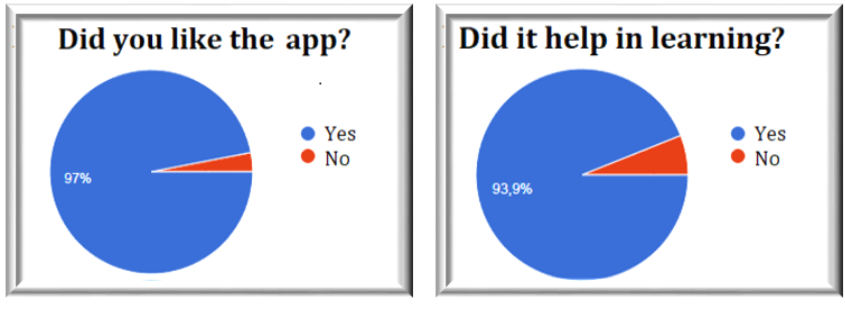


Figure 13. Quizlet: asymptotics - match



(a) Liking *(b)* Usability

Figure 14. Quizlet:Studendts' opinion on the set

Students' opinion about the Quizlet was positive; 33 out of 43 students dealt with the task. (This means 77% participation, which is a very high rate at the university.) Everyone except one student liked using it, (Figure 14a) and everyone except two students said that the application was helpful for learning.(Figure 14b) Interestingly, even those who did not like this game said that it helped them to learn, and the two students who did not regard Quizlet as especially helpful said that they liked it.

Although it was not mandatory to write an opinion on it, I received more comments than I expected. Some of these are as follows: *"Useful and easy to learn.", "Very good, so I noticed that I have shortcomings.", "It summarizes what you need to know, so I find it very useful and cool.", "Ideal and helps a lot to put the knowledge you have acquired in practice: D"*

Impact of Gamification on Courses

In order to see the benefits of gamification, I compared the results of my experimental groups with the results of other groups whose course curricula did not include gamification. The completion of the course consists of two-step; first students must obtain a practical grade and then take an exam. Although the primary purpose of the course I held was to obtain a practical grade, I compared the results of both grades.

Comparison of practical grades

During the semester I applied the principle of gamification in two groups. For the control group, I used the previous year's groups, who had followed the traditional attended the course. The first group was called "Innovative Group" and the second group "Test Group". The two innovative and the two test groups were of the same type; one of them was a fixed group specialization B and the other one was a standard group specialization C. (Fixed-group admissions are limited to students who have passed all the exams. If someone fails one of the exams, they can only enroll in a standard group. Generally, the best-performing students will choose specialization B. C is the general specialization, which most students choose.) It means I had an above-average and a a group with lower ability students in both years.

During the semester, students had to write a classroom test. The test of the Test Group consisted of 5 tasks, which were to be solved within 1.5 hours, but whoever wanted was given extra time. Because I wanted to encourage the Innovative Group to use the "opportunities", the Innovative Group's test consisted of 6 tasks, and they were given 1.5 hours. They were allowed to use the "opportunities" and write the test longer. Five tasks of the test were similar to the those of the Test Group, whereas in task 6 students had to write an algorithm using a learned technique. (This type of task is the most difficult for them.) Therefore, the Innovative Group had to solve a harder test in the same amount of time than the Test Group. Students in the specialization B Test Group scored an average of 38.3 points, while the average score of the members of the Innovative Group was 42.4. As for specialization C students, the Test Group achieved an average of 33.8 points, while the Innovative Group scored 38.44.

Practical grades differed more than the result of the tests: as for specialization B students, the average of the Test Group was 3.73, while that of the Innovative Group was 4.54, i.e. the Innovative Group performed better by almost one (0.81)

grade. The specialization C group also performed better in the Innovative Group: the mean of the Test Group was 3.38 and the average of the Innovative Group was 3.72. (The difference here is only 0.34.)

The results also show that students took advantage of the optional scoring opportunities; thus they invested more time (and more work) in the course during the semester.

Comparing Examination Grades

When analyzing the exam grades, I chose a different Test Group. I thought that my survey better would reflect reality by comparing the performance of study groups with the same tasks, so I chose the all the students of the semester as a Test Group.

For specialization B, the point average of the Test Group was 3.15, and that of the Innovative Group was 3.48, i.e. students in the Innovative Group received by over 30% higher grades.

The average grade of specialization C was 2.37, whereas the average of the Innovative Groupwas 2.6, representing a nearly one-quarter (0.23) increase. (Even though the Innovative Group here is standard, and the semester has more fixed groups.)

Summary

Experience-based learning builds on our curiosity as a natural component of our functioning as human beings. The drive is a very strong urge that accompanies us from our childhood. There may be a lot of hindrances in the learning process, such as lack of motivation or disinterest. However, if experience-based teaching can turn our knowledge into a problem-solving skill, then we might be successful.

If the new knowledge of the learning process can relate to an appropriate experience, it greatly contributes to the deepening and later recalling knowledge.

As the generation that is growing up today was born into an online world, education must also open towards smart devices. One way to do this is to use gamification in education. In my article, besides introducing gamification, I have shown several possibilities for using it at school. In addition, I have investigated the impact of gamification in "Algorithms and Data Structures" university course on the student.

The high participation of students in the experiment, their feedback, and the result of the experiment clearly confirmed that gamification might have an important role in higher education, as well.

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