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A GAMIFIED WEB ASSISTANT FOR SUPPORT OF LEARNING PROCESS

Introduction

Lifelong study is one of the key features of modern society. However, each age group of learners requires specific teaching methodologies to organize studying process in the most efficient way. One of the most flexible teaching methodology is gamification of the learning process [1-4, 10]. Gamification offers a wide spectrum of mechanics to introduce into the learning process in order to make it interesting for learners of different ages [5-9].

Recent researches prove the efficiency of gamification introduction into the educational process [1-4, 10]. However, most of them are focusing on the theoretical or methodological aspects of this process without introduction of the respective hardware and / or software solutions [5-9]. While being possibly more engaging, hardware gamification solutions could be too expensive in order to be affordable for an average school or university, especially in developing countries. Therefore, software solutions can be more affordable because of requiring only a computer or computer-like portable device for their usage.

Many of existing educational solutions with gamification feature onboard introduce only several mechanics being more an interactive book rather than a game [11-14]. In most cases, it results in insufficient level of learner's engagement looking like a game being a reward for learner's effort. At the same time, games with practical educational elements have proved to be effective in both engagement and learning outcome e.g. a game that incorporates tasks related to specific topics in secondary school physics course [10]. In order to beat levels and bosses in this game, pupils should use specific knowledge from the physics course. Players wish to complete the game and therefore return to a specific topic of the textbook. This is how the game fuels the learning effort while raising the engagement level.

Despite possessing high level of engagement, educational games are always at risk of turning into an entertainment without significant learning outcomes. One way of saving the balance between entertainment and education is to introduce both practice and theory in the game turning it into a useful assistant for teachers and learners.

The goal of this research is to develop a gamified web assistant to support Chemistry, English, HTML/CSS and Mathematics courses.

The scientific novelty consists of successful development of the gamified web assistant to support Chemistry, English, HTML/CSS and Mathematics courses ensuring up to 37% higher level of enjoyment of learning in comparison to regular learning while maintaining the learning outcomes at the sufficient level.

Gamified web assistant

In terms of software development, there is always a question of what platform to choose [10, 15]. Mobile devices are more flexible in terms of where and when to study and cheaper than computers. On the other hand, smaller screen size can be inconvenient when it comes to texts, formulas and visualization of graphs or spatial objects. Besides, there are multiple options concerning operation systems that remain a topical issue for both portable and stationary devices. Despite all the described advantages and disadvantages, the short answer for question "What platforms to cover?" is "All of them!"

In order to cover most of the existing platforms, two options are available:

1) development of the standalone build for each platform;

2) development of the web application.

The first option offers more stable solutions, high quality graphics, and theoretically unlimited access to system resources. On the other hand, there are high development and support costs because of hiring iOS, Android, Windows, Mac OS, Linux, etc. developers and technical specialists and respective license payments [3, 15]. Although cross-platform technologies can be used, bug-tracking support costs for each platform cannot be omitted.

The second option while offering limited access to system resources and mid-range quality of graphics is significantly more inexpensive in terms of development and support [3, 15]. However, web applications are sensitive to network issues and this disadvantage should be taken into account.

In this project, the second option is chosen because it offers cross-platform and inexpensive solutions considering that nowadays an Internet connection is widely available at home and at the educational institution. Thus, a web assistant for support of learning process is developed and tested. The proposed solution offers assistance in teaching Chemistry, English, HTML/CSS and Mathematics. The web application consists of four top-level components corresponding to each of the mentioned subjects.

Chemistry component

The Chemistry component aims at enhancing learner's skills in several topics of this subject. This component consists of a game with multiple levels matched a single plot. In the proposed game, the user takes on the role of a hero tasked with saving a princess from the castle full of locked doors, traps, puzzles and mysterious enemies.

The first level of the game offers a descriptive example of the whole component gameplay. To successfully navigate this level, the player must thoroughly study the following topics: "Acids," "Bases," and "Chemical Equations." The essence of the gameplay at this level lies in utilizing flasks containing various acids (Fig. 1). Each lock on the castle doors is composed of a specific material. The player must dissolve these locks by applying specific acids to them in order to open the doors and help the hero to get into castle. Because of material specificity, not all of the locks "interact" with a particular liquid in the flasks. Thus, the player needs to apply previously acquired knowledge to distribute resources correctly.

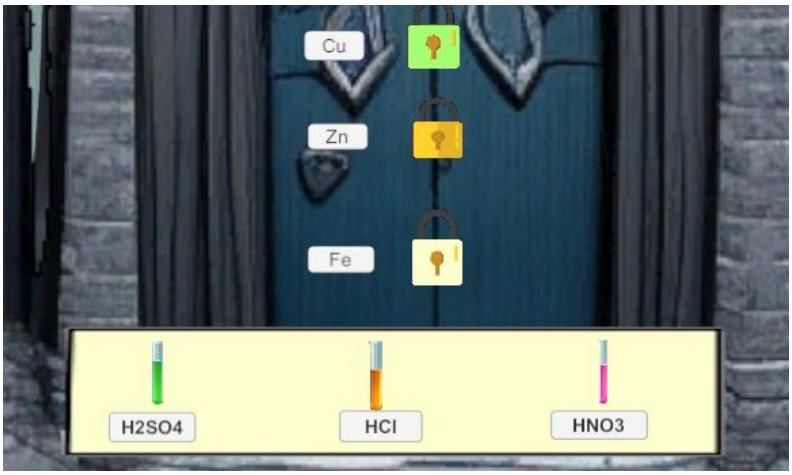

Fig. 1. The first level of the Chemistry component

The described level utilizes the following chemical equations [16]:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g), \quad (1)$$

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l), \quad (2)$$

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g), \quad (3)$$

where (s) denotes solid physical state, (aq) denotes aqueous solution, (g) denotes gas physical state, (l) denotes liquid physical state.

In the reaction (1), zinc (Zn) reacts with hydrochloric acid (HCl). The basic idea is that an acid reacts with a metal to form a salt and release hydrogen. In this context, hydrochloric acid reacts with zinc, dissolving it and forming salt and hydrogen. In the reaction (2), copper (Cu) reacts with nitric acid (HNO_3). In this context, nitric acid reacts with copper, dissolving it and forming a salt (copper nitrate), nitrogen oxide gases and water. In the reaction (3), iron (Fe) reacts with sulfuric acid (H_2SO_4). In this context, sulfuric acid reacts with iron, dissolving it and forming salt and hydrogen [16].

In case of insufficient knowledge and application of wrong acid to the lock, the player loses the respective substance and gets the opportunity to retry only after a certain time interval. The last measure prevents the learner from brute forcing the solution and encourages them to refer to the theoretical part of the course.

English component

The English component is a platform with several tabs offering distinct activities. The first tab offers tests that are divided into 4 levels of difficulty: A1, A2, B1, and B2. The essence of the test is that a random word in English appears on the screen, and 4-6 answer options are shown proposing different translations. The user's task is to choose the correct answer (Fig. 2). Levels B1 and B2 are initially locked. In order to unlock them, the player needs to pass the first level. The test is considered to be passed successfully if the percentage of correct answers is greater than or equal to 80. The test also has a timer, which can be paused. The time provided for each test is 10 minutes. Tests are always randomly generated, e.g. two consecutive A1 tests will be different in both questions and their number. B1 and B2 tests include idioms and phrases, and the user needs to choose the correct interpretation.

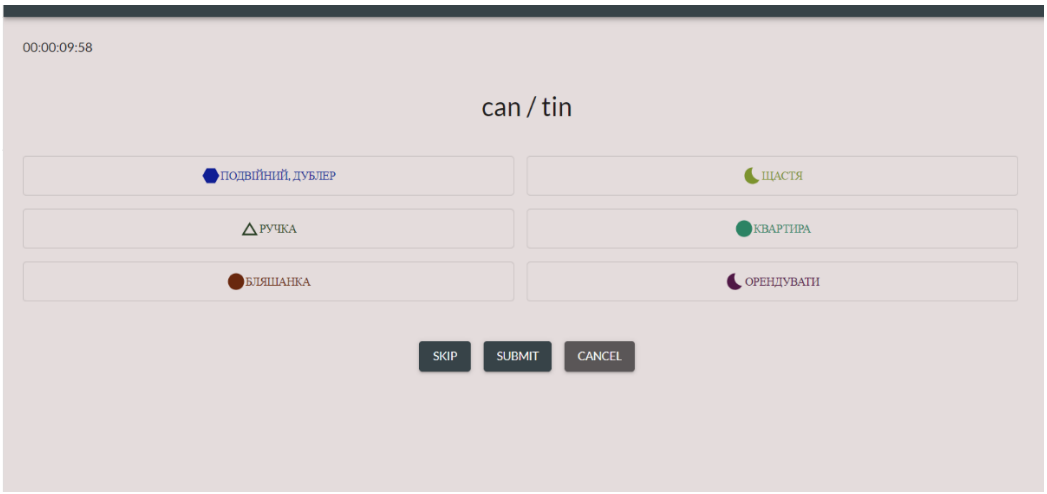

Fig. 2. Interface of an English test (6 answer options are given in Ukrainian)

The principle of closed levels is a good example of implementation for gamification because it offers a "journey to success". Each closed level is a new stage of learner's journey. In order to unlock the next level, users should successfully complete the current one. Thus, each level becomes a challenge but also an opportunity to discover content that is even more interesting. The principle of closed level also implements a concept of gradual development because the gamified system mimics the process of gradual development [1, 3, 4, 6]. Closed levels in this case represent degrees or stages of development that the user must pass to reach new heights.

Additionally, the platform analyzes the statistics of each attempt, and the player is able to see it in a separate tab (Fig. 3). The statistics show the completion time, answers chosen, and correct answers. With a help of statistics tab, the learner can summarize their progress and analyze mistakes in order to fill the gaps in their vocabulary.

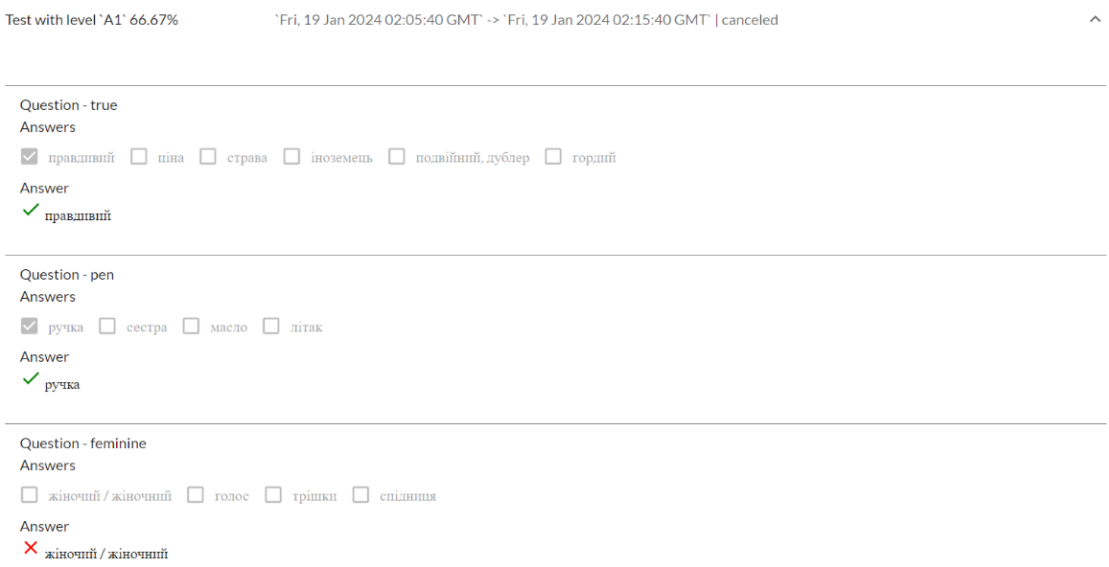

Fig. 3. Interface of a statistics tab

The third tab offers a platformer game. The player controls the main character, who embarks on a journey through an impressive structure filled with dangers (Fig 4). The player's task is to avoid various obstacles such as spikes, moving platforms, collapses, and other hazards that may threaten the hero's life.

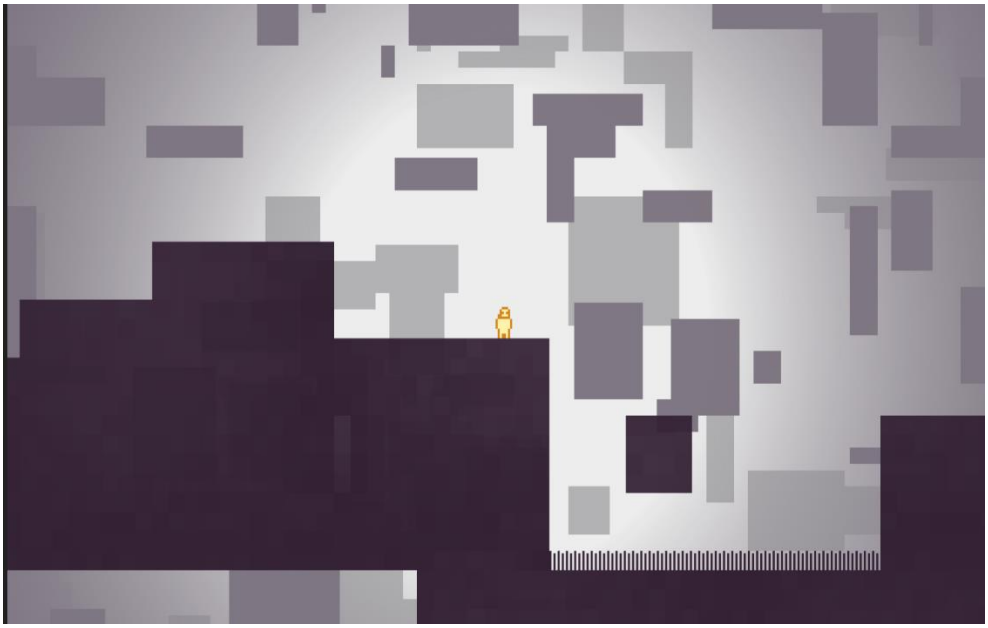

Fig. 4. Interface of the platformer game in English component

Along the way, the player will encounter chests located on different levels of the game. Each chest contains a word in player's native language that the player must translate. This word could be a key element for solving a puzzle on the next level or further stages of the game. For example, the player may encounter a chest with the word "light." After opening the chest, the player receives the word "light." This word turns out to be important for understanding a certain puzzle on the next level or subsequent stages of the game. The game effectively utilizes the interactivity of the platformer, combining it with puzzle elements and an educational component. This makes it interesting and challenging for players of all ages and language proficiency levels.

HTML/CSS component

The HTML/CSS component offers a collectible card game for learning HTML/CSS. This approach combines theory learning with practical exercises. The game-based card learning for HTML/CSS aims to teach the basics of working with HTML and CSS using a card-based mechanism. The player receives cards with specific concepts, properties, or tags, such as "background-color," "border," "div," etc. The information on these cards helps learners to grasp the theoretical aspects of programming languages.

One of the key aspects of this game is its gamified approach. The player is rewarded with code cards that they can use to build their own web elements. This mechanism resembles collecting collectible cards and motivates the player to continue learning.

After learning the theoretical part, the player could test their knowledge in task mode. In this mode, the player is presented with specific tasks, such as creating elements with certain properties, which they must reproduce using their own cards. For example, the player is tasked with creating a blue square with a red border (Fig. 5).

Fig. 5. Task presentation before its completion in HTML/CSS component

In order to complete the task, the player should choose the correct combination of cards corresponding the correct combination of HTML elements and CSS rules (Fig. 6). The player can observe the results of current card combination and alter the cards chosen, grab new cards from the deck or ask the game for a hint. The more cards are in player's deck, the more complicated tasks they can accept in order to progress further.

Game-based card learning for HTML/CSS reflects modern approaches to education, combining gamification with the acquisition of programming theory [1-3, 6, 7]. This method stimulates active player participation and promotes effective learning, making the learning process more engaging.

Mathematics component

The Mathematics component consists of two major modules: learning module with tasks typical for class-based lessons and gamified module with in-game tasks utilizing the learned theoretical part of the certain topic.

The landing page of the learning module is a lobby with levels to be unlocked by completing the previous ones (Fig. 7). Each level consists of several stages containing theory and practical tasks. The level is completed if all its corresponding tasks are solved correctly.

Fig. 6. Completed task appearance in HTML/CSS component

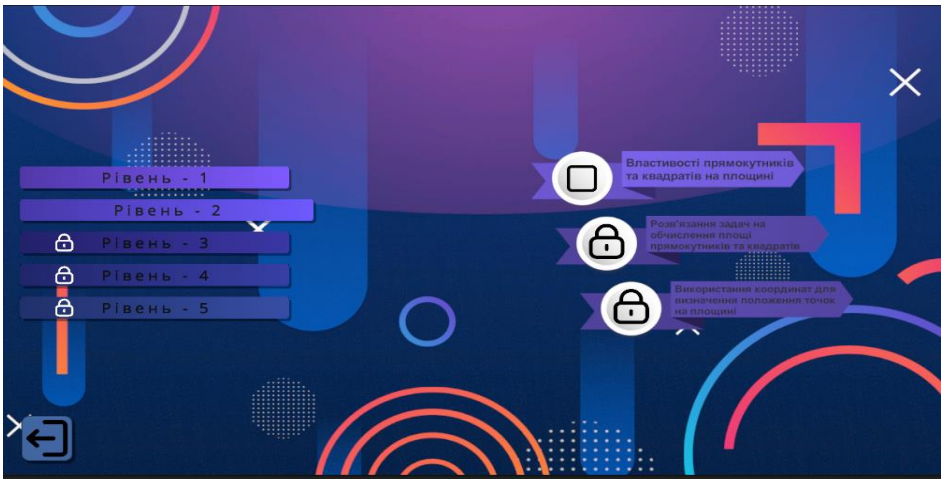

Fig. 7. Lobby with levels in the learning module of the Mathematics component

The gamified module offers a game "Forest under threat: Hero with mathematical abilities". The main character, while studying mathematics, finds out that thieves are trying to destroy the forest and decides to use their mathematical skills to save the home of forest dwellers. The gameplay consists of solving mathematical puzzles, enlisting forest dwellers for a help, and expelling the thieves. For example, player can place a trap for thieves by simplifying the given algebraic expression. In case of a battle scenario, the player is tasked to place the forest warriors in vertices of the rectangular with area equal to 20 m2, etc. As all preparations are done, the battle scene starts (Fig. 8) and the player can observe the outcomes, analyze their strategy, and correct mistakes if the battle was unsuccessful.

Combination of knowledge application and elements of a strategic game produces a high level of motivation for learners to improve their math skills in both theory and practice.

Effectiveness test

The efficiency analysis was performed with the help of group of 12 undergraduate adult students of the “Information Systems and Technologies” program at Vasyl Stefanyk Carpathian National University in Ivano-Frankivsk, Ukraine, who volunteered to provide their feedback required to estimate the benefits of the proposed web assistant.

Fig. 8. Battleground in the gamified module of the Mathematics component

Half of the group was offered to study the following topics:

- "Chemical equations" in Chemistry;
- "B1 vocabulary" in English;
- "Box model: styling" in HTML/CSS;
- "Geometric figures on the plane" in Mathematics;

using the proposed web assistant. The rest of the students were offered to study the same topics in a regular way using books, learning videos, etc. After the completion of the learning course all volunteers were tested for their knowledge with the same tests resulting in the mark in range from 1 to 10 points for each of the learning courses. They were also asked to rank their experience in terms of learning engagement and enjoyment of learning in range from 1 to 10 points for each of the learning courses.

The average values of the given ranks were calculated excluding the highest and lowest values using the following expression (4) [3, 8]:

$$TrimMean = \frac{\sum_{i=1}^{n} x_i - n_{\max} x_{\max} - n_{\min} x_{\min}}{n - n_{\max} - n_{\min}}, \quad (4)$$

where x_i denotes the ith rank (in points), $i=1,\ldots,n$, n denotes the number of ranks, $n_{\max}$ denotes the number of the highest ranks, $x_{\max}$ denotes the value of the highest rank, $n_{\min}$ denotes the number of the lowest ranks, $x_{\min}$ denotes the value of the lowest rank.

The calculated average rank values for every course can be found in table 1 for the proposed web assistant and in table 2 for the regular learning. Table 3 contains the ratios between the data in table 1 and table 2 showing the advantage of the proposed solution over the regular learning process.

Table 1

Average estimation ranks for the proposed web assistant

Course	Learning outcomes	Learning engagement	Enjoyment of learning
Chemistry	6.76	5.92	7.04
English	7.23	7.61	6.08
HTML/CSS	8.04	8.43	8.22
Mathematics	5.64	6.50	7.37

Table 2

Average estimation ranks for the regular learning

Course	Learning outcomes	Learning engagement	Enjoyment of learning
Chemistry	6.65	7.33	5.84
English	7.04	6.04	5.32
HTML/CSS	7.73	6.63	6.48
Mathematics	7.39	6.23	5.38

Table 3

Ratios between average estimation ranks for the proposed web assistant and the regular learning

Course	Learning outcomes	Learning engagement	Enjoyment of learning
Chemistry	1.02	0.81	1.21
English	1.03	1.26	1.14
HTML/CSS	1.04	1.27	1.27
Mathematics	0.76	1.04	1.37

Obtained results can be visualized using radar diagrams (Fig. 9) in order to comprehend advantages and disadvantages of the proposed solution in comparison to the regular learning process.

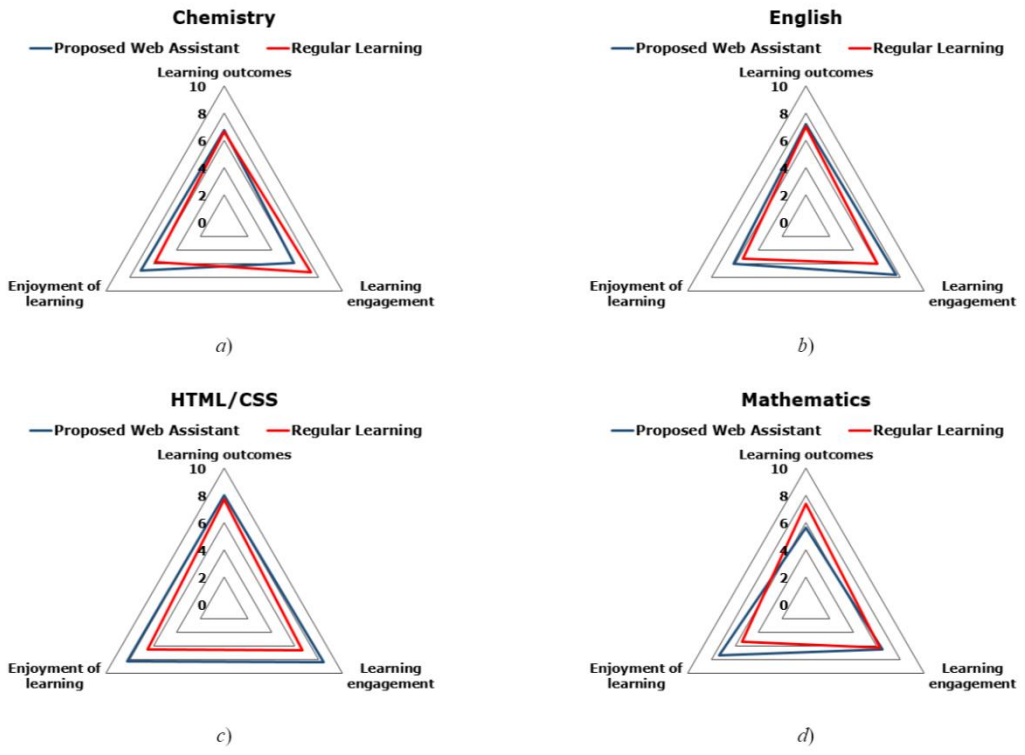

Fig. 9. Radar diagrams of the average estimation ranks for the proposed web assistant and the regular learning for the Chemistry course (a), for the English course (b), for the HTML/CSS course (c), and for the Mathematics course (d)

From the results obtained (Table 3 and Fig. 9) it follows that introduction of the proposed web assistant shows distinct level of efficiency for different courses. In case of Chemistry, learning outcomes are on the same level as for regular learning, however learning engagement is 19% lower while enjoyment of learning is 21% higher. Large number of learning videos demonstrating real chemical reactions that are always engaging probably causes lower learning engagement rank. This

result seems to be scalable for the real-world classes with chemical reactions right before the learner's eyes.

In case of English, learning outcomes are 3% higher, while engagement and enjoyment are 26% and 14% higher respectively. It seems that learning vocabulary depends not on the motivation level but on learner's abilities to learn the foreign language.

In case of HTML/CSS course, learning outcomes are 4% higher, while engagement and enjoyment are both 27% higher. The reason for the not so high performance at learning outcomes is the professional skills of the study participants. They are all proficient at programming, so it is not hard for them to learn how to code from regular sources full of code listings. At the same time, all participants highly appreciated the gamified way of learning how to code, so the proposed solution seems to be optimistic at learning outcomes improvement in case of learners not experienced in programming.

In case of Mathematics, learning outcomes are 24% lower, while engagement and enjoyment are 4% and 37% higher respectively. It seems that learners tend to lose focus while playing the game or they can just brute force solutions without understanding the task requirements to progress through the game. At the same time, gamified Mathematics course is in demand in order to make the learning process not so boring.

Conclusions

The proposed web assistant offers an engaging and enjoyable learning process for different courses but obviously has its flaws. While the Chemistry course requires engaging visualizations of the chemical reactions and Mathematics course requires balancing in order to stop learners from brute forcing it, the whole application raises the level of enjoyment of learning up to 37% in comparison to regular learning. It means that application of the proposed web assistant in learning process can reduce the stress of learners on the corresponding value while maintaining the learning outcomes at a slightly higher level.

Further studies consist of polishing the existing gamification mechanics and introducing the new ones and gathering feedback from learners and teachers at educational institutions.

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