Research on the feasibility of employing gamification technologies in the training process of IT specialization seekers

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Abstract

Despite the significant amount of published work on gamification in education, many aspects remain unexplored. Including question of gamification in gender perspectives and age-related considerations that has not been investigated yet. Amount of evidence-based researches, long-term studies and effective recommendations on gamifying educational content are equal to zero. The aim of this study is to find out the feasibility of introducing gamification technologies into the process of training applicants for IT majors. To achieve this aim, various scientific research methods were used, including literature analysis, experiments, result comparisons, and data analysis techniques. Multiple hypotheses on the effectiveness of gamification technologies in the process of training applicants for IT majors were formulated and investigated. Specifically, the study examined if there's a significant correlation between participation levels in gamified courses and overall learning effectiveness, if active time spent in gamified courses positively impacts effectiveness, and if task completion relates to learning improvement for each specific task. Visualizations of the obtained results have been conducted. Particularly, a Scatter Plot with Regression Line has been constructed to depict the relationship between the level of participation in the gamified course and overall academic performance. Additionally, a Heat map correlation matrix has been created to display the level of dependence between the number of attempts for each test and the final exam score, along with other graphs. Python library tools in the Jupyter Notebook environment facilitated these analyses. In conclusion, participation in the gamified course positively impacts learning effectiveness, although its strength may vary depending on specific conditions.

Keywords

Data Science, Data Mining, gamification of education, scatter plot, regression line, heat map correlation

1. Introduction

Due to global trends in development of the digital economy and society, the process of digitization becomes a necessity. The modern world is evolving rapidly, technologies are constantly changing, and education remains a sustainable support for societal development. The digitization of society brings in its requirements on the preparation of future specialists, necessitating changes in the technologies used in the educational process. The era of digital education demands new methods and tools for the training of modern professionals.

Ukraine, like most of the civilized world, is integrating information technologies into its educational system. In 2019, the Ministry of Education and Science of Ukraine chose modernization of national education as the main direction of reforms. The main goal of this modernization is to create current and attractive education for the "digital generation" of students, who primarily use smartphones, consume information from Wikipedia and YouTube, communicate and interact in virtual spaces and social networks [1, 2].

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Today, gamification occupies a special place in the educational process [3, 4]. Gamification is the application of gaming practices and mechanisms in non-game contexts with the aim of engaging end-users in problem-solving [5, 6]. It emphasizes achieving a specific goal rather than the game itself. Among the most popular forms of gamifying the educational process are using games as a teamwork tool, a tool for acquiring practical skills, and a tool for psychological influence [7, 8, 9, 10, 11]. As for the most popular directions of using IT technology in the educational process, these include gamification directly within the learning process, interactive textbooks, organizing microlearning, personalized learning, VR/AR formats, etc [8].

Combining gamification methods with IT technology capabilities is considered one of the most prespective directions for motivating learners in education.

2. Literature review

Given the relevance of this topic, we encounter thousands of publications in scholarly journals related to the use of gamification in the educational process for its improvement. For instance, Silva et al. [12] investigating the application of gamification in studying various management fields, identified approximately 1300 publications in the scientific databases Web of Science and Scopus dedicated to this topic. Silva et al. [12] outline the main theoretical principles and constructs of gamification based on a comprehensive review of academic articles available in the Web of Science and Scopus databases, synthesizing conclusions from various studies. The primary focus of this publication was on exploring gamified learning in different management fields.

The term "gamification" itself emerged in the 1980s. The first real projects using gamification methods to enhance business interaction with customers and employees were implemented in the late 2000s. Therefore, most academic publications of that time focused on establishing theoretical foundations and terminology for gamification. The theoretical basis of gamification in education, including terminology, methods, approaches, etc., has been elucidated by Zichermann and Cunningham [6], Deterding et al. [13], Kumari [14], Huotari and Hamari [15], Kapp [16].

Most academic publications on gamification in the educational process are highlighted in psycho-pedagogical studies examining the impact of gamification on learner motivation. These studies include those by Pereiaslavska and Kozub [8], McGonigal [17], Cheng-Yu Hung and Yu [18], Abramovich et al. [19], Hickey and Rehak [20], Guin et al. [21], Savchenko [22], Smotr et al. [23], Chen et al. [24], Deterding [25], Iaremenko [26], Kupchak et al. [27]. However, as noted by the authors themselves, their studies are quite generalized and require further investigation. Typically, these studies are conducted on small statistical samples, focusing on the effect of increased motivation in the early stages of engaging individuals in learning, without considering the effects of habituation and loss of interest in specific gaming techniques. Long-term studies are necessary to accurately assess the lasting effects of gamification.

Studies on the effectiveness of gamification, considering age factors, are also quite generalized and can be divided into three age groups: primary education, secondary education, and higher education. Works by Savchenko [22], Karabin [28], Kochengina and Koval [29], Kudykina [30], Bludova and Ilina [31], Yaremii and Haliuka [32] are dedicated to the impact of gamification on primary school student preparation. Gamification in the educational process of junior high school is highlighted by Pereiaslavska and Kozub [8], Buzko and Echkalo [33], Kiptilyi [34], Salata and Trukhan [35], Fidria [36]. Mekhed [3], Ibáñez et al. [37], Kahu [38], Skaskiv [39], Zakharova and Gruzd [40], Kupchak et al. [27] explore gamification in higher education. These studies partially explain what content of gamified education can be used for each age category. However, they do not consider age as a variable that could explain differences in the use of gamified educational content, motivation, and emotional perception.

Among academic publications on gamification in the educational process, another segment deserves attention. These are publications dedicated to examining gamification in specific educational domains. Such works partially link the selection of gamification elements to the educational content. Among the publications in this segment, we can mention the works by Silva et al. [12], Buzko and Echkalo

[33], Ibáñez et al. [37], Duran et al. [41], Mladenović et al. [42], Bugaeva [43], Gama et al. [44], Fidria [36].

3. Problem statement

However, despite a considerable number of publications on the use of gamification in the educational process, many aspects remain unexplored. Specifically, none of the reviewed publications examined gamification from a gender perspective, and long-term studies are lacking. Yet, only such research can provide an understanding of whether learners of different genders react similarly to the same gamification methods and whether their response to gamification methods remains consistent over an extended period. As both loss of interest due to habituation to gamification elements and increased interest due to experience with such elements are possible, along with a consequent reduction in fear of the un- known, long-term studies are essential to assess the level of residual knowledge acquisition over time. Since there is a risk that engagement with gamification elements may divert learners' attention from mastering the material itself, in- stead focusing their efforts on gaining ratings, points, level progression, and so forth, which in turn may lead to short-term knowledge retention.

Furthermore, as previously mentioned, studies on gamification considering the age factor are also quite generalized, divided only into three age groups: primary school, secondary school, and higher education. For instance, it would be interesting to examine in more detail the reaction to specific gamification elements by the same learners in different years of their education. Alternatively, assessing the attitudes towards the same gamification elements among students in junior and senior years of higher education institutions would provide valuable insights.

Besides, it can be argued that the extent to which gamification tools are investigated, and their suitability for various educational components and special- ties, remains incompletely explored. Currently, there are no well-founded studies or recommendations on how to gamify the educational process according to the specificity of educational content. Presently, the application of gamification methods and tools in the educational process has outpaced scholarly research.

We have decided to investigate the effectiveness of implementing gamification technologies in the training process of IT specialization seekers using methods of data analytics.

We will formulate several hypotheses regarding the effectiveness of implementing gamification technologies in the training process of IT specialization seekers and explore them using statistical methods. We will utilize the Python library tools within the interactive development environment of Jupyter Notebook.

1. Hypothesis about the relationship between participation and performance:
Testing whether there is a statistically significant relationship between the level of participation in a gamified course and overall learning effectiveness.

2. Hypothesis about the effect of active time on productivity:
Investigating whether there is a positive correlation between the active time students spend in a gamified course and their performance.

3. Hypothesis about the relationship between the number of completed tasks and performance:
Examining whether there is a relationship between the number of completed tasks and the improvement in learning performance for each specific task.

4. Hypothesis about the effectiveness of individual exercises:
Comparing the effectiveness of different exercises to determine which aspects of gamification are most useful for improving learning outcomes.

5. Hypothesis about the influence of the use of gamification technologies on different groups of students:
Investigating whether the use of gamification technologies affects the learning outcomes of different groups of students (eg, by race or gender).

6. Hypothesis about the effectiveness of using gamification technologies in different academic years:
Comparing learning outcomes between different academic years to determine if gamification is more effective in certain periods.

4. Methods and tools for studying the effectiveness of gamification technologies

For studying the effectiveness of gamification in education, there are several methods that can be used:

- *Experimental study.* It consists in comparing the learning results of groups, one of which uses gamification technologies, and the other does not.
- *Questionnaire.* Educators can be surveyed and graded to find out how much they like gamification and how it helps them learn.
- *Poll.* The method makes it possible to investigate the attitude of education seekers to gamification in education.
- *Comparison of results.* The researcher can compare the learning outcomes obtained through gamification with the results obtained in the past without gamification.

In each of these research methods, it's important to consider factors such as the age of the learners, their level of knowledge and experience in the relevant discipline, the specialty they are studying, and the quality of the gamified material being used. Additionally, the researcher should ensure a sufficiently large sample of learners to draw meaningful conclusions and validate the hypothesis.

Data Science is one of the fastest-growing fields in the modern world, enabling the analysis of large volumes of data to discover patterns and obtain valuable insights. Data Science methods include statistical analysis, machine learning, deep learning, natural language processing, and others. As part of the Data Science toolkit, we can mention popular tools such as the interactive development environment Jupyter Notebook, which allows for creating and executing Python code, and Python libraries like Pandas, Plotly, Matplotlib and Seabornfor data processing and visualization.

At the initial stage of any Data Science research, one of the challenges is to find an appropriate dataset. Today, one of the largest public web platforms with a significant number of open datasets is Kaggle. Therefore, we turned to this platform at the beginning of our research on the effectiveness of gamification technologies to search for a suitable dataset for our study.

As of March 2024, the Kaggle platform hosted over 320,000 diverse datasets. Among them, there were approximately eight and a half thousand datasets related to education. However, refining the search query and specifically searching for datasets related to both "Education" and "Gamification" revealed that there were only two such datasets on the Kaggle platform: "Gamification in education" and "Bellabeat - Case Study".

With the aim of finding more relevant datasets and considering the purpose of our research, a parallel search query was conducted focusing on the criteria "Gamification" and "Computer science". As a result of this query, another dataset was found: "Impact of Gamification Software Testing Education".

So, in summary, we obtained 3 datasets that met the specified criteria. Reviewing the metadata of these datasets revealed that we can work with only two of them: "Gamification in education" and "Impact of Gamification Software Testing Education".

The "Bellabeat - Case Study" dataset was created by collecting data from the FitBit fitness tracker. Data collection was organized to investigate the comfort of fitness technology, teach weight management, and encourage light activity to improve users' overall health. It's evident that the purpose of collecting data in this dataset and the information it contains does not align with the goal of our research.

The "Gamification in education" dataset was created as students used a gamified program for learning with interactive cards and badges to engage them in studying statistics and multidimensional statistical

analysis. The dataset contains information on grades for practical exams before using the educational platform, grades for final exams after using the platform, whether a student is a user of the platform, the average score for each of the six tests, and the number of times exercises were completed.

The "Impact of Gamification Software Testing Education" dataset includes materials related to the use of testing software provided to learners as educational resources, as well as the software applications SQLTest and GoRace. These programs were integrated to support the gamification experience and served as tools that students used for their learning activities [45].

So we can consider only two datasets: "Gamification in education" and "Impact of Gamification Software Testing Education". Let's use experimental research methods and compare the results.

5. Experiment, results and discussion

Initially, we extensively investigated the chosen datasets. Primarily, we determined the dimensions of this dataset, what specific data it contains, their type, quantity, quality, the presence of outliers and duplicates, etc.

To determine the dimensionality of the datasets, we used the 'shape' command. We received feedback (69,16) (figure 1) for the "Gamification in education" dataset and (235,32) (figure 2) for the "Impact of Gamification Software Testing Education" dataset. This indicates that there are a total of 235 rows and 32 columns in this dataset. Therefore, the "Gamification in education" dataset contains information on the education of 69 learners, while the "Impact of Gamification Software Testing Education" dataset contains information on 235 learners.

Figure 1: Dimensionality of the "Gamification in education" dataset.

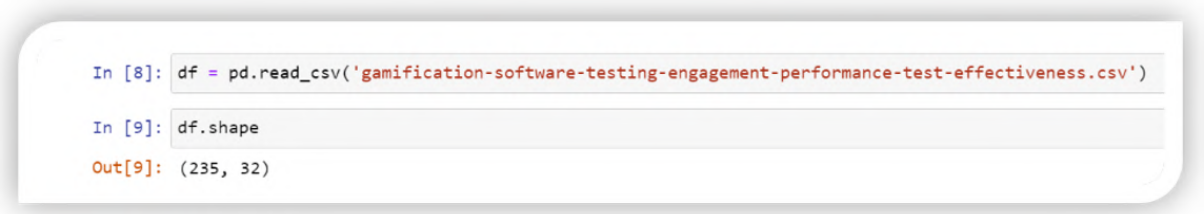


Figure 2: Dimensionality of the "Impact of Gamification Software Testing Education" dataset

General information regarding the "Gamification in education" and "Impact of Gamification Software Testing Education" datasets is depicted in figure 3 and figure 4 respectively.

At the next stages, the data from the datasets were checked for missing values, duplicates, outliers, etc. No duplicates or outliers were found in either of the datasets. Regarding missing values, there were only 12 in the first dataset and 74 in the second (total for 5 tasks). Therefore, we can assert that the number of missing values is insignificant, so there is no need to remove irrelevant columns. Additionally, since it is known from the dataset annotations that missing values indicate that the learner did not attempt the task or did not pass the exam, we replaced missing values with '0'.

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 69 entries, 0 to 68
Data columns (total 16 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   Student_ID     69 non-null     int64
 1   Practice_Exam  57 non-null     float64
 2   Final_Exam     69 non-null     float64
 3   User           69 non-null     int64
 4   Avg_Grade_Q1   69 non-null     float64
 5   Avg_Grade_Q2   69 non-null     float64
 6   Avg_Grade_Q3   69 non-null     float64
 7   Avg_Grade_Q4   69 non-null     float64
 8   Avg_Grade_Q5   69 non-null     float64
 9   Avg_Grade_Q6   69 non-null     float64
 10  No_access_Q1   69 non-null     int64
 11  No_access_Q2   69 non-null     int64
 12  No_access_Q3   69 non-null     int64
 13  No_access_Q4   69 non-null     int64
 14  No_access_Q5   69 non-null     int64
 15  No_access_Q6   69 non-null     int64
dtypes: float64(8), int64(8)
memory usage: 8.8 KB
```

Figure 3: Summary information about the "Gamification in education" dataset.

After analyzing the content of both datasets, we concluded that based on the "Gamification in education" dataset, we can only test the first two hypotheses we formulated. With the "Impact of Gamification Software Testing Education" dataset, we can test the first, second, and third hypotheses. Unfortunately, none of the selected datasets will allow us to test the four, fifth and sixth hypotheses, as there is no information in either dataset about gender, race, demographic location of the learners, etc.

We'll attempt to determine whether the use of a gamified educational platform leads to improved exam results. That is, we'll test our first hypothesis "Hypothesis about the relationship between participation and performance". We'll test this hypothesis on both datasets and compare the results obtained. Comparing results from different datasets can help us understand how general or universal the identified relationship between participation and performance is in gamified courses.

5.1. First hypothesis testing (on the "Gamification in education" dataset)

To test the 1st hypothesis, we compared the average exam scores before and after learners started using the gamified platform. Additionally, we compared the average scores across six tests between learners who were users of the gamified platform and those who were not using a t-test.

For conducting the t-test and comparing the distribution of scores between two groups, we followed the following plan of action:

1. Formulated the null and alternative hypotheses:
    - *Null hypothesis:* "There is no difference in scores between students who used the platform and those who did not".

```
In [12]: df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 235 entries, 0 to 234
Data columns (total 32 columns):
 #   Column                                Non-Null Count  Dtype
---  ------                                --------------  -----
 0   Academic Year                         235 non-null    object
 1   ID Student                            235 non-null    object
 2   Race Effectiveness                    235 non-null    int64
 3   Exercise1 Effectiveness               235 non-null    int64
 4   Exercise2 Effectiveness               235 non-null    int64
 5   Exercise3 Effectiveness               231 non-null    float64
 6   Exercise4 Effectiveness               216 non-null    float64
 7   Race Effectiveness Increase           235 non-null    float64
 8   Exercise1 Effectiveness Increase      235 non-null    float64
 9   Exercise 2 Effectiveness Increase     235 non-null    float64
 10  Exercise3 Effectiveness Increase      231 non-null    float64
 11  Exercise4 Effectiveness Increase      216 non-null    float64
 12  Race Participation                    235 non-null    int64
 13  Exercise1 Participation               235 non-null    int64
 14  Exercise2 Participation               235 non-null    int64
 15  Exercise3 Participation               231 non-null    float64
 16  Exercise4 Participation               215 non-null    float64
 17  Race Dropout                          235 non-null    int64
 18  Exercise1 Dropout                     235 non-null    int64
 19  Exercise2 Dropout                     235 non-null    int64
 20  Exercise3 Dropout                     235 non-null    int64
 21  Exercise4 Dropout                     231 non-null    float64
 22  Race Active Time                      235 non-null    int64
 23  Exercise1 Active Time                 235 non-null    int64
 24  Exercise2 Active Time                 235 non-null    int64
 25  Exercise3 Active Time                 235 non-null    int64
 26  Exercise4 Active Time                 235 non-null    int64
 27  Race Number Executions                235 non-null    int64
 28  Exercise1 Number Executions           235 non-null    int64
 29  Exercise2 Number Executions           235 non-null    int64
 30  Exercise3 Number Executions           235 non-null    int64
 31  Exercise4 Number Executions           235 non-null    int64
dtypes: float64(10), int64(20), object(2)
memory usage: 58.9+ KB
```

Figure 4: Summary information about the “Impact of Gamification Software Testing Education” dataset.

- *Alternative hypothesis:* “The scores of students who used the platform are different from the scores of those who did not”.

2. Divided the data into two groups: learners who used the platform and those who did not. To separate into two groups, we added a new column ’Platform User’ to the dataframe and filled it with ’Yes’ if the learner was a user of the gamified platform and ’No’ otherwise.

3. Used the ttest-ind function from the scipy.stats module to conduct a t-test on independent samples. Passed two data groups (group1 and group2, corresponding to the groups of users of the gamified platform and those who were not).

For example, the result of the t-test for comparing the results of learners’ performance on the ’Avg-Grade-Q3’ test from the “Cluster Analysis” is shown in figure 5.

The p-value is significantly smaller than the specified alpha value (typically 0.05), so we can reject the null hypothesis and conclude that there is a statistically significant difference between the two groups. For visual comparison of the score distribution between the two groups, we used the matplotlib functions to construct a histogram and a density plot for the two user groups (figure 6).

On the histogram, you can see that the score distribution for the group of users of the gamified platform is skewed to the right, while for the group that did not use the gamified platform, the score distribution is almost symmetric. The density plot also demonstrates this, where the distribution curves for the two groups show that most scores for the platform users were higher than for the non-platform

```
In [30]: group1 = df[df["Platform User"] == "Yes"]["Avg_Grade_Q3"]
         group2 = df[df["Platform User"] == "No"]["Avg_Grade_Q3"]

In [31]: #from scipy.stats import ttest_ind
         t, p = ttest_ind(group1, group2)
         print("t-value:", t)
         print("p-value:", p)

         t-value: 9.646006756244063
         p-value: 2.703881978510649e-14
```

Figure 5: Result of conducting a t-test to compare the performance results of two user groups.

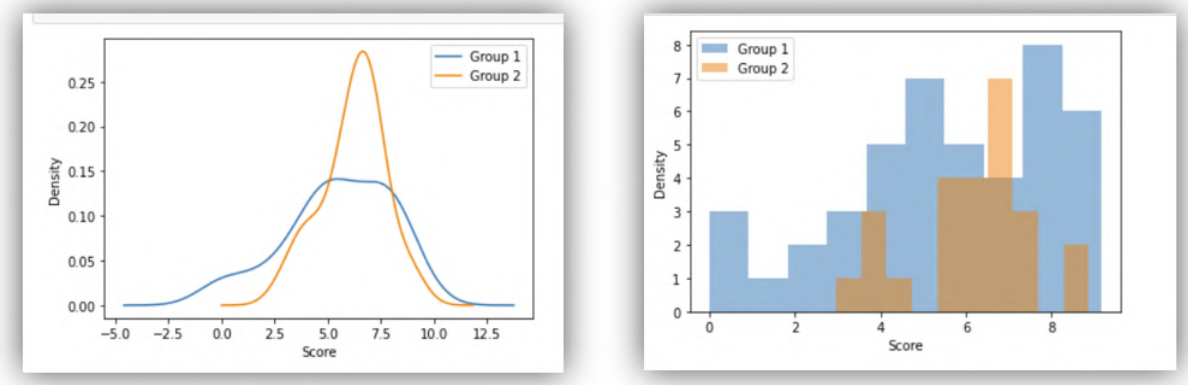


Figure 6: Density plot and histogram comparing the score distribution between two user groups (Group 1 – users of the gamified platform; Group 2 – learners who did not use the gamified platform).

```
# Calculating Pearson's correlation and p-value for a data set «Gamification in education»
correlation, p_value = pearsonr(df1['Platform User'], df1['Final_Exam'])

print("Correlation between participation and performance:", correlation)
print("p-value:", p_value)

Correlation between participation and performance: 0.3905134821071693
p-value: 0.0009087145027949805

# Calculating Pearson's correlation and p-value for a data set «Impact of Gamification Software Testing Education»
correlation, p_value = pearsonr(df2['Race Participation'], df2['Race Effectiveness'])

print("Correlation between participation and performance:", correlation)
print("p-value:", p_value)

Correlation between participation and performance: 0.5817344872909987
p-value: 1.11623890692471e-22
```

Figure 7: Pearson's correlation and p-value for the dataset "Gamification in education" and the dataset "Impact of Gamification Software Testing Education".

users. We computed the Pearson correlation coefficient and p-value between participation in the gamified course and performance for both datasets (figure 7).

We see that in the first dataset, the correlation is 0.3905, indicating a positive relationship, but it is slightly weaker than in the second case. In the second dataset, the correlation between participation and performance is 0.5817, indicating a moderate positive relationship between these two variables.

In the second dataset, the p-value is very small (practically zero), indicating the statistical significance of the obtained correlation. In the first dataset, the p-value is also small, but not as extremely small as

in the second case.

We can conclude that both datasets show a statistically significant positive relationship between participation in the gamified course and learning performance. In the second dataset, the correlation is moderate, which may indicate a stronger relationship between participation and performance in that context. In both cases, the p-value is very small, confirming the statistical significance of the results obtained.

Thus, the visual and numerical results confirm our initial hypothesis that learners who were users of the platform scored higher on the final exam compared to those learners who did not use the gamified platform.

5.2. Second hypothesis testing

Let's test 2nd hypothesis: "Hypothesis about the impact of active engagement on performance". Learners who engage more frequently with interactive cards and badges will have higher scores on final exams.

To test this hypothesis, we will calculate the correlation between the number of attempts for each test, the average score for each test, and the final exam score. We will use the 'corr' function from the Pandas library.

First, for the dataset "Gamification in education" , we created two new columns. One column named "Total Attempts", which will contain the total number of attempts for each test by learners, and another column named "Total Score", which will contain the overall score of the learners for all tests. This allowed us to compute the correlation between the number of attempts for each test, the average score for each test, and the final exam score. To visually represent this, we will construct a heatmap of the correlation matrix for the dataset "Gamification in education".

The values on the main diagonal (from top left to bottom right) will be equal to 1 because the correlation with itself is always 1. Other values in the matrix demonstrate the degree of dependency between variables. For example, the correlation value between the number of attempts for each test and the final exam score will indicate how these variables are related to each other. For better visualization of the results obtained, it's worth displaying the correlation matrix as a heatmap (figure 8).

Interpreting the results of the analysis (lighter colors indicate stronger correlation), we can make the following conclusions:

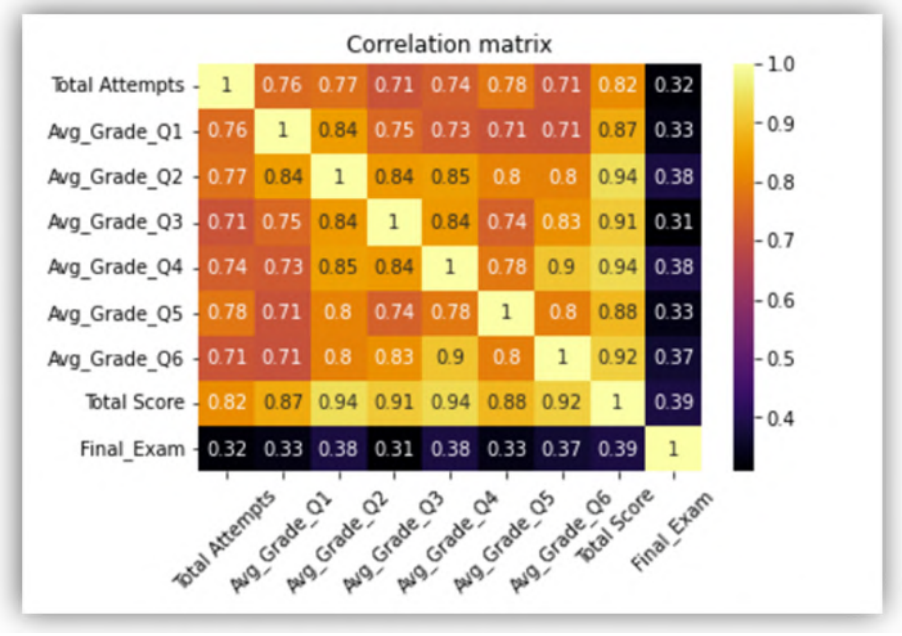


Figure 8: Heat map correlation matrix.

- There is a strong positive correlation between the number of attempts for Test 2 and Test 4 and the final exam score;
- There is a moderate positive correlation between the average score for Test 1 and the final exam score, as well as between the number of attempts for Test 5 and the final exam score;
- There is a weak positive correlation between the average score for Test 3 and the final exam score, as well as between the number of attempts for Test 6 and the final exam score.

Overall, we can conclude that there is some dependence between the test results and the final exam score. Thus, we practically confirmed the validity of our 2nd hypothesis. Therefore, summarizing the results, we can argue that using gamification elements in the study of educational components containing elements of statistical analysis and mathematical statistics is justified.

5.3. Third hypothesis testing

Let's test our 3rd hypothesis: "Hypothesis about the relationship between the number of completed tasks and performance" on the dataset "Impact of Gamification Software Testing Education". We will determine whether there is a dependency between the number of completed tasks and the improvement of learning efficiency for each specific task.

To test 3rd hypothesis regarding the relationship between the number of completed tasks and performance, we applied linear regression analysis for each specific task separately to assess the influence of the number of completed tasks on performance. Then, for each task, we evaluated the statistical significance of the relationship between the number of completed tasks and performance, and what specific impact the number of completed tasks has on performance.

The results of the linear regression analysis for tasks "Exercise1" to "Exercise4" are shown respectively in figures 9-12.

The results of the linear regression analysis for "Exercise1" can be interpreted as follows:

OLS Regression Results

Dep. Variable:	Race Effectiveness	R-squared:	0.338
Model:	OLS	Adj. R-squared:	0.336
Method:	Least Squares	F-statistic:	119.2
Date:	Sun, 14 Apr 2024	Prob (F-statistic):	1.12e-22
Time:	23:50:40	Log-Likelihood:	-1001.9
No. Observations:	235	AIC:	2008.
Df Residuals:	233	BIC:	2015.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	72.3091	1.646	43.923	0.000	69.066	75.553
Race Participation	24.6429	2.257	10.917	0.000	20.196	29.090

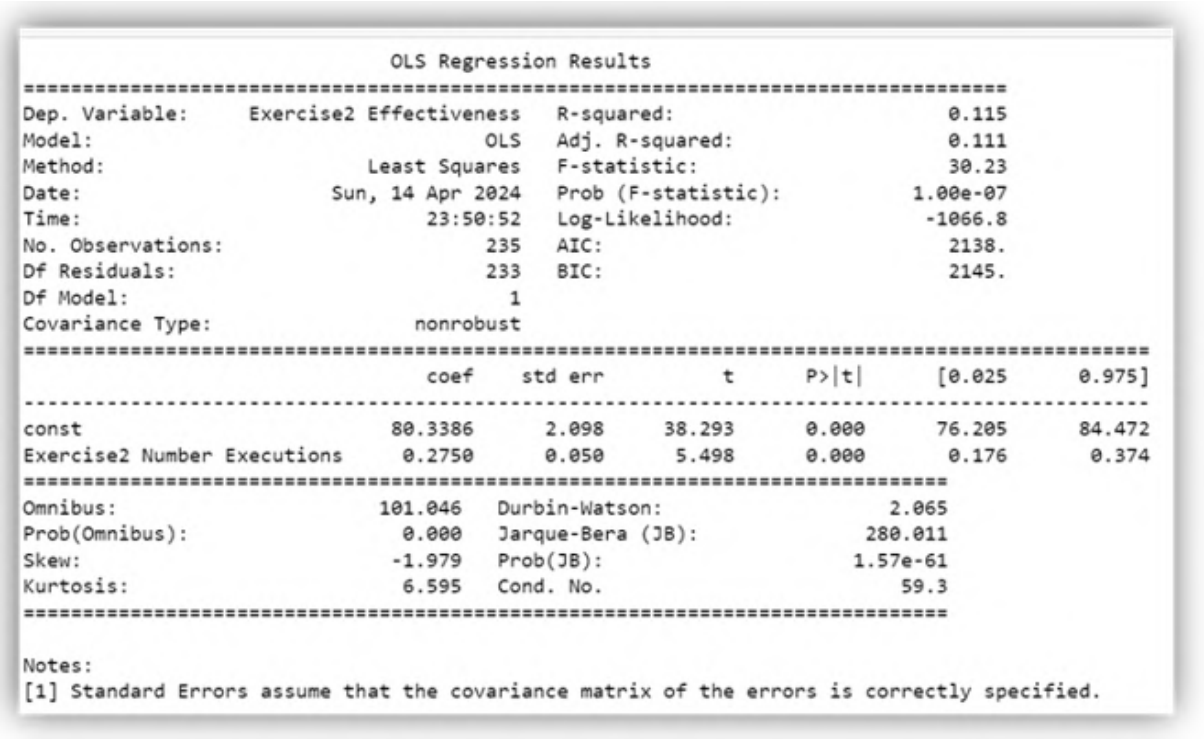
Omnibus:	41.598	Durbin-Watson:	1.935
Prob(Omnibus):	0.000	Jarque-Bera (JB):	65.737
Skew:	-0.997	Prob(JB):	5.31e-15
Kurtosis:	4.655	Cond. No.	2.70

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Figure 9: Results of linear regression analysis for "Exercise1".

- R-squared (R^2): The coefficient of determination R^2 is 0.030. This means that approximately 3% of the variation in student performance in Exercise1 can be explained by changes in the number of executions. This value is relatively low, indicating that the number of executions doesn't explain a significant portion of the variability in performance.
- Coefficient for Exercise1 Number Executions: The coefficient for the variable "Exercise1 Number Executions" is 0.1489. This means that for each additional execution, the performance in Exercise1 increases by an average of 0.1489 units.
- p-value: The p-value for the coefficient of "Exercise1 Number Executions" is 0.008. This value is less than 0.05, indicating the statistical significance of the relationship between the number of executions in Exercise1 and performance.

In other words, the variable "Exercise1 Number Executions" is statistically significant in explaining the change in performance.



OLS Regression Results

Dep. Variable:	Exercise2 Effectiveness	R-squared:	0.115
Model:	OLS	Adj. R-squared:	0.111
Method:	Least Squares	F-statistic:	30.23
Date:	Sun, 14 Apr 2024	Prob (F-statistic):	1.00e-07
Time:	23:50:52	Log-Likelihood:	-1066.8
No. Observations:	235	AIC:	2138.
Df Residuals:	233	BIC:	2145.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	80.3386	2.098	38.293	0.000	76.205	84.472
Exercise2 Number Executions	0.2750	0.050	5.498	0.000	0.176	0.374

Omnibus:	101.046	Durbin-Watson:	2.065
Prob(Omnibus):	0.000	Jarque-Bera (JB):	280.011
Skew:	-1.979	Prob(JB):	1.57e-61
Kurtosis:	6.595	Cond. No.	59.3

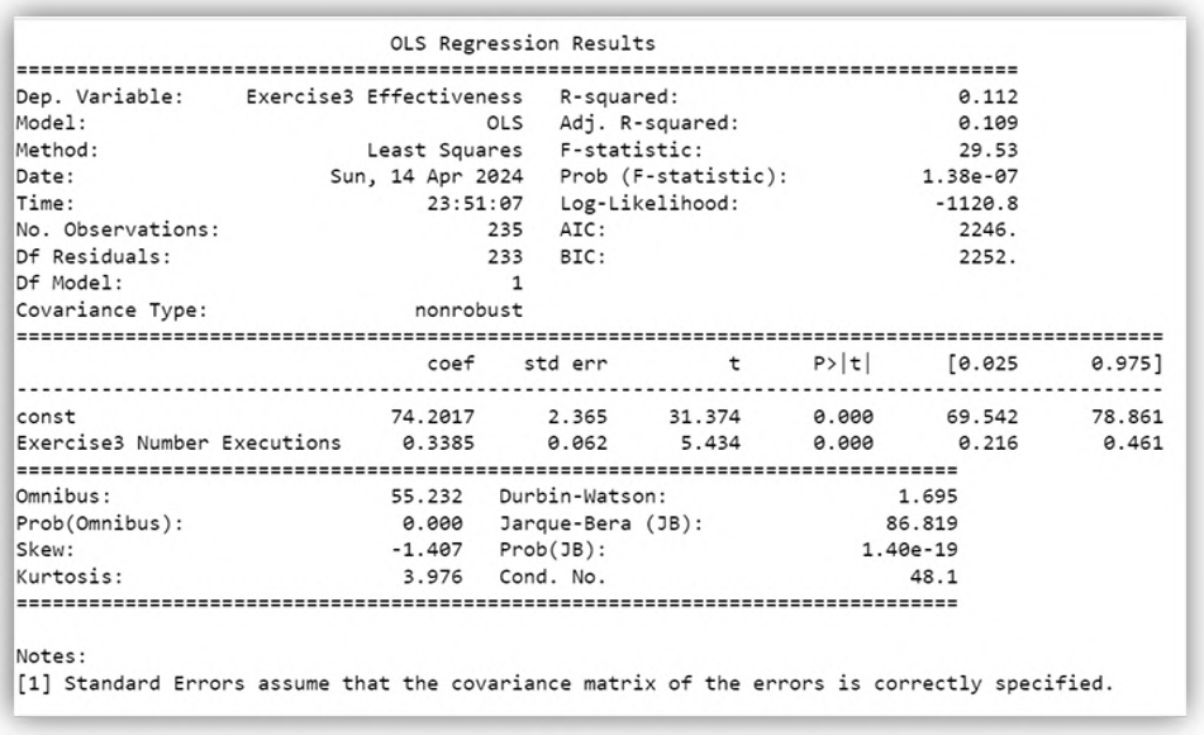
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Figure 10: Results of linear regression analysis for "Exercise2".

The results of the linear regression analysis for "Exercise2" can be interpreted as follows:

- R-squared (R^2): The coefficient of determination R^2 is 0.115. This means that approximately 11.5 % of the variation in students' performance in Exercise2 can be explained by changes in the number of tasks completed. This indicates that the number of tasks completed can explain a portion, but not all, of the variability in results.
- Coefficient for Exercise2 Number Executions: The coefficient for the variable "Exercise2 Number Executions" is 0.2750. This means that with each additional task completed, the average performance in Exercise2 increases by 0.2750 units.
- p-value: The p-value for the coefficient of "Exercise2 Number Executions" is 0.000, which is much less than 0.05. This indicates a statistically significant influence of the number of tasks completed in Exercise2 on students' performance.

Overall, the results indicate that for Exercise2, the number of tasks completed has a statistically significant positive impact on students' performance. Each additional task completed, on average, leads to an increase in Exercise2 performance by 0.2750 units.



OLS Regression Results

Dep. Variable:	Exercise3 Effectiveness	R-squared:	0.112
Model:	OLS	Adj. R-squared:	0.109
Method:	Least Squares	F-statistic:	29.53
Date:	Sun, 14 Apr 2024	Prob (F-statistic):	1.38e-07
Time:	23:51:07	Log-Likelihood:	-1120.8
No. Observations:	235	AIC:	2246.
Df Residuals:	233	BIC:	2252.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	74.2017	2.365	31.374	0.000	69.542	78.861
Exercise3 Number Executions	0.3385	0.062	5.434	0.000	0.216	0.461

Omnibus:	55.232	Durbin-Watson:	1.695
Prob(Omnibus):	0.000	Jarque-Bera (JB):	86.819
Skew:	-1.407	Prob(JB):	1.40e-19
Kurtosis:	3.976	Cond. No.	48.1

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Figure 11: Results of linear regression analysis for "Exercise3".

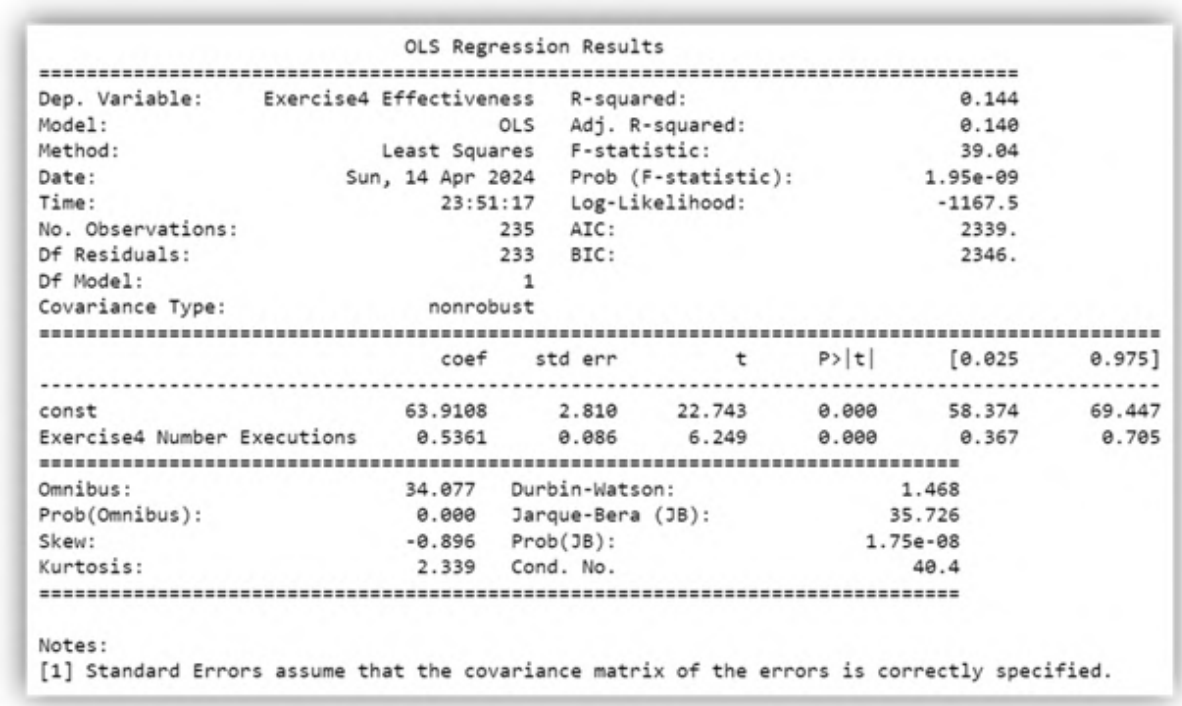
The results of the linear regression analysis for the "Exercise3" task can be interpreted as follows:

- R-squared (R^2): The coefficient of determination R^2 is 0.112. This means that approximately 11.2% of the variation in students' performance in the Exercise3 task can be explained by changes in the number of tasks completed. This indicates that the number of tasks completed can explain some, but not all, of the variability in results.
- Coefficient for Exercise3 Number Executions: The coefficient for the variable "Exercise3 Number Executions" is 0.3385. This means that with each additional task completed, the performance in the Exercise3 task increases by an average of 0.3385 units.
- p-value: The p-value for the coefficient for "Exercise3 Number Executions" is 0.000, which is much less than 0.05. This indicates a statistically significant impact of the number of tasks completed in the Exercise3 task on students' performance.

So, the analysis shows that for the Exercise3 task, the number of tasks completed has a statistically significant positive impact on students' performance. Each additional completed task on average leads to an increase in performance in the Exercise3 task by 0.3385 units.

The results of the linear regression analysis for the "Exercise4" task can be interpreted as follows:

- R-squared (R^2): The coefficient of determination R^2 is 0.144. This means that approximately 14.4% of the variation in students' performance in the Exercise4 task can be explained by changes in the number of tasks completed. This indicates that the number of tasks completed can explain some, but not all, of the variability in results.
- Coefficient for Exercise4 Number Executions: The coefficient for the variable 'Exercise4 Number Executions' is 0.5361. This means that with each additional task completed, the performance in the Exercise4 task increases by an average of 0.5361 units.



OLS Regression Results

Dep. Variable:	Exercise4 Effectiveness	R-squared:	0.144
Model:	OLS	Adj. R-squared:	0.140
Method:	Least Squares	F-statistic:	39.04
Date:	Sun, 14 Apr 2024	Prob (F-statistic):	1.95e-09
Time:	23:51:17	Log-Likelihood:	-1167.5
No. Observations:	235	AIC:	2339.
Df Residuals:	233	BIC:	2346.
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	63.9108	2.810	22.743	0.000	58.374	69.447
Exercise4 Number Executions	0.5361	0.086	6.249	0.000	0.367	0.705

Omnibus:	34.077	Durbin-Watson:	1.468
Prob(Omnibus):	0.000	Jarque-Bera (JB):	35.726
Skew:	-0.896	Prob(JB):	1.75e-08
Kurtosis:	2.339	Cond. No.	40.4

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Figure 12: Results of linear regression analysis for “Exercise4”.

- p-value: The p-value for the coefficient for ’Exercise4 Number Executions’ is 0.000, which is much less than 0.05. This indicates a statistically significant impact of the number of tasks completed in the Exercise4 task on students’ performance.

Therefore, the analysis shows that for the Exercise4 task, the number of tasks completed has a statistically significant positive impact on students’ performance. Each additional completed task on average leads to an increase in performance in the Exercise4 task by 0.5361 units.

For a visual representation of the dependencies between the number of tasks completed and performance for each specific task, taking into account different years of study, we have constructed scatter plots with regression lines for each task for each year of study using the Seaborn library (figure 13).

In the scatter plots (figure 13), the x-axis represents the number of tasks completed, and the y-axis represents performance. Additionally, a regression line is added to show the trend of performance change with increasing number of tasks completed. Each year is represented by a different color on the plot.

In summary, based on the results obtained, it can be concluded that the number of tasks completed has a statistically significant positive impact on students’ performance”.

5.4. Unresolved issues

However, it is worth noting that the sample size of the investigated datasets is quite limited. Additionally, given the presence of other fields in the datasets, a much larger number of studies could have been conducted, and other hypotheses could have been tested. For example, it could have been explored whether there are individual differences in the effectiveness of the gamified learning platform. Specifically, hypothesis 5 could have been tested: “Hypothesis 5: Platform effectiveness will depend on individual differences, such as prior knowledge of statistics and learning preferences”. To test this hypothesis, it would have been appropriate to conduct a series of regression analyses to investigate the relationship between platform usage and exam outcomes while controlling for individual differences such as prior knowledge, motivation, and engagement. Additionally, exploring potential moderation effects would have been beneficial.

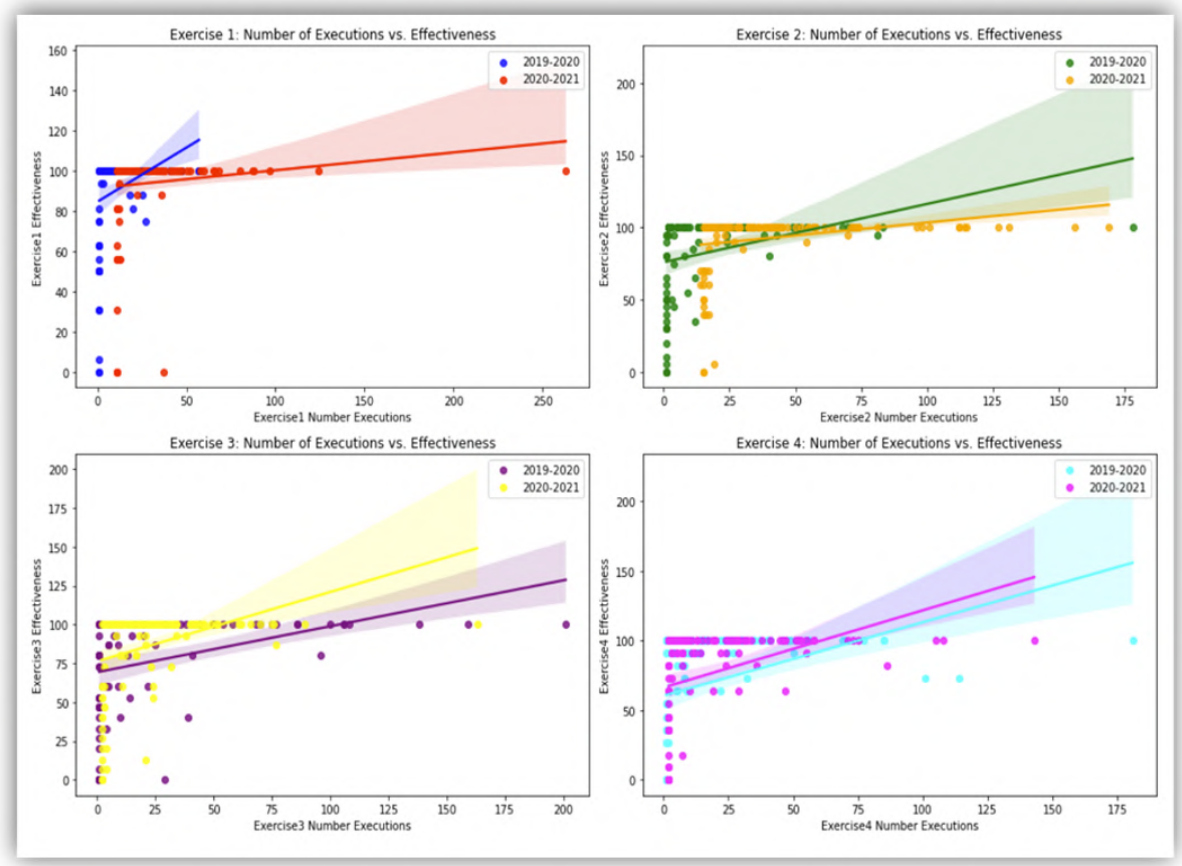


Figure 13: Scatter plots with regression lines for each exercise (Exercise1-Exercise4) for each year of study.

Alternatively, the question could be investigated: "Does the gamified learning platform improve retention of statistical knowledge over time?" This is hypothesis number 6: "Hypothesis 6: Students using the gamified platform will have better long-term retention of statistical knowledge compared to those who do not use the gamified platform". To test this hypothesis, it would be appropriate to conduct a repeated measures analysis of variance to compare the practical exam results before and after using the platform, as well as during a follow-up assessment after several months. Additionally, it would be important to determine whether the platform's impact on long-term retention varies based on individual differences (such as motivation, engagement).

6. Conclusions

We have formulated and investigated several hypotheses regarding the effectiveness of implementing gamification technologies in the training process for IT learners. Specifically, we examined whether there is a statistically significant relationship between the level of participation in the gamified course and overall learning effectiveness; whether there is a positive correlation between active time spent by students in the gamified course and their effectiveness; and whether there is a relationship between the number of tasks completed and learning improvement for each specific task. Comparisons of learning outcomes were made across different academic years, among other factors.

We visualized the obtained results, including constructing a scatter plot with regression line to display the relationship between the level of participation in the gamified course and overall learning effectiveness. We also created a correlation plot of active time and effectiveness to illustrate the correlation between active time spent and effectiveness. Additionally, we generated a heat map correlation matrix to demonstrate the impact of active time spent on the gamified platform on learner performance.

One of the key findings of the study is that gamification can be an effective tool for increasing

motivation among IT education learners and improving their academic performance.

It is important to note that implementing gamification technologies in education comes with its challenges, such as selecting appropriate tools, increasing workload to create gamified materials, and organizing the learning process using them. However, considering the possibilities of modern technologies and the proper use of gamification in education, it can become an effective tool in improving the quality of education.

References

[1] Hanna Novosad predstavyla komandu MON: priorytetamy roboty stanut doshkillia, pryshvydshennia NUSh, reforma PTO, pidtrymka krashchykh u vyshchii osviti ta nautsi, 2019. URL: https://tinyurl.com/bdhfmy8u.

[2] V. Y. Bykov, Digital transformation of society and development of the computer technology platform of education and science of Ukraine, in: Materials of the methodological seminar of the National Academy of Pedagogical Sciences of Ukraine "Information and Digital Educational Space of Ukraine: Transformation Processes and Development Prospects", National Aviation University, 2019, pp. 20–26. URL: https://lib.iitta.gov.ua/id/eprint/718692/.

[3] K. Mekhed, Gamification in education as an innovative means of realizing the competency approach at higher educational establishments, Herald of the National University "Chernihiv Collegium" named after T. G. Shevchenko 163 (2020) 19–22. doi:10.5281/zenodo.3758978.

[4] E. G. Fedorenko, N. V. Kaidan, V. Y. Velychko, V. N. Soloviev, Gamification when studying logical operators on the Minecraft EDU platform, in: S. H. Lytvynova, S. O. Semerikov (Eds.), Proceedings of the 4th International Workshop on Augmented Reality in Education (AREdu 2021), Kryvyi Rih, Ukraine, May 11, 2021, volume 2898 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2021, pp. 107–118. URL: https://ceur-ws.org/Vol-2898/paper05.pdf.

[5] K. Huotari, J. Hamari, Defining gamification: a service marketing perspective, in: Proceeding of the 16th International Academic MindTrek Conference, MindTrek '12, Association for Computing Machinery, New York, NY, USA, 2012, p. 17–22. doi:10.1145/2393132.2393137.

[6] G. Zichermann, C. Cunningham, Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps, O'Reilly, 2011. URL: http://www.oreilly.de/catalog/9781449397678/index.html.

[7] K. Mechus, O. Smotr, N. Vovchastaya, M. Rashkevich, Doslidzhennia problematyky vprovadzhennia tekhnolohii heimifikatsii u systemu osvity, in: zbirnyk tez dopovidei IV Mizhnarodnoi naukovo-praktychnoi konferentsii, IBIT 2022, m. Lviv, 30 lystopada 2022 roku, RASTR-7, Lviv, 2022, pp. 353–356. URL: https://sci.ldubgd.edu.ua/jspui/handle/123456789/11544.

[8] S. O. Pereiaslavska, H. O. Kozub, Heimifikatsiia u navchalnomu protsesi shkoly : posib. do vyvchennia dysts. dlia stud. spets. 014. – „Serednia osvita", DZ „LNU imeni Tarasa Shevchenka", Luhansk, 2021. URL: https://dspace.luguniv.edu.ua/xmlui/handle/123456789/7094.

[9] T. A. Vakaliuk, V. V. Kontsedailo, D. S. Antoniuk, O. V. Korotun, I. S. Mintii, A. V. Pikilnyak, Using game simulator Software Inc in the Software Engineering education, in: A. E. Kiv, M. P. Shyshkina (Eds.), Proceedings of the 2nd International Workshop on Augmented Reality in Education, Kryvyi Rih, Ukraine, March 22, 2019, volume 2547 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2019, pp. 66–80. URL: https://ceur-ws.org/Vol-2547/paper05.pdf.

[10] O. M. Haranin, N. V. Moiseienko, Adaptive artificial intelligence in RPG-game on the Unity game engine, in: A. E. Kiv, S. O. Semerikov, V. N. Soloviev, A. M. Striuk (Eds.), Proceedings of the 1st Student Workshop on Computer Science & Software Engineering, Kryvyi Rih, Ukraine, November 30, 2018, volume 2292 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2018, pp. 143–150. URL: http://ceur-ws.org/Vol-2292/paper16.pdf.

[11] O. O. Katsko, N. V. Moiseienko, Development computer games on the Unity game engine for research of elements of the cognitive thinking in the playing process, in: A. E. Kiv, S. O. Semerikov, V. N. Soloviev, A. M. Striuk (Eds.), Proceedings of the 1st Student Workshop on Computer Science

& Software Engineering, Kryvyi Rih, Ukraine, November 30, 2018, volume 2292 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2018, pp. 151–155. URL: http://ceur-ws.org/Vol-2292/paper17.pdf.

[12] R. Silva, R. Rodrigues, C. Leal, Gamification in management education: A systematic literature review, BAR - Brazilian Administration Review 16 (2019). doi:10.1590/1807-7692bar2019180103.

[13] S. Deterding, M. Sicart, L. Nacke, K. O'Hara, D. Dixon, Gamification: Using game design elements in non-gaming contexts, in: Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems, volume 66, 2011, pp. 2425–2428. doi:10.1145/1979742.1979575.

[14] S. Kumari, Gamification: An Employee Engagement Strategy for Organizations of 21st Century, in: N. Sharma, N. Chaudhary, V. K. Singh (Eds.), Management Techniques for Employee Engagement in Contemporary Organizations, IGI Global, 2019, p. 199–217. doi:10.4018/978-1-5225-7799-7.ch012.

[15] K. Huotari, J. Hamari, Defining gamification: a service marketing perspective, in: Proceeding of the 16th International Academic MindTrek Conference, Association for Computing Machinery, New York, NY, USA, 2012, p. 17–22. doi:10.1145/2393132.2393137.

[16] K. Kapp, The gamification of learning and instruction: Game-based methods and strategies for training and education, Pfeiffer, San Francisco, CA, 2012.

[17] J. McGonigal, Reality is broken: Why games make us better and how they can change the world, Penguin Press, New York, NY, 2011. URL: https://hci.stanford.edu/courses/cs047n/readings/Reality_is_Broken.pdf.

[18] J. C.-Y. S. Cheng-Yu Hung, P.-T. Yu, The benefits of a challenge: student motivation and flow experience in tablet-PC-game-based learning, Interactive Learning Environments 23 (2015) 172–190. doi:10.1080/10494820.2014.997248.

[19] S. Abramovich, C. Schunn, R. Higashi, Are badges useful in education?: It depends upon the type of badge and expertise of learner, Educational Technology Research and Development 61 (2013). doi:10.1007/s11423-013-9289-2.

[20] D. Hickey, A. Rehak, Wikifolios and participatory assessment for engagement, understanding, and achievement in online courses, Journal of Educational Media and Hypermedia 22 (2013) 407–441. URL: https://learntechlib.org/p/41508/.

[21] T. D.-L. Guin, R. Baker, J. Mechling, E. Ruyle, Myths and Realities of Respondent Engagement in Online Surveys, International Journal of Market Research 54 (2012) 613–633. doi:10.2501/IJMR-54-5-613-633.

[22] O. Savchenko, Diagnostics and didactic conditions for the formation of motivation to learn in junior schoolchildren, Ukrainian Pedagogical Journal (2015) 85–98. URL: https://lib.iitta.gov.ua/id/eprint/9773/.

[23] O. Smotr, M. Rashkevich, R. Golovatyi, K. Mechus, Vykorystannia instrumentariiu informatsiinykh tekhnolohii dlia pidvyshchennia motyvatsii studenta do navchannia u formati zmishanoi osvity, in: M. S. Koval, N. H. Nychkalo (Eds.), Informatsiino-komunikatsiini tekhnolohii v suchasnii osviti: dosvid, problemy, perspektyvy, volume 6, Lviv State University of Life Safety, Lviv, 2021, pp. 214–217.

[24] C.-H. Chen, G. Liu, G.-J. Hwang, Interaction between gaming and multistage guiding strategies on students' field trip mobile learning performance and motivation, British Journal of Educational Technology 47 (2015) 1032–1050. doi:10.1111/bjet.12270.

[25] S. Deterding, Gamification: designing for motivation, Interactions 19 (2012) 14–17. doi:10.1145/2212877.2212883.

[26] N. V. Iaremenko, Enhancing English language learners' motivation through online games, Information Technologies and Learning Tools 59 (2017) 126–133. doi:10.33407/itlt.v59i3.1606.

[27] M. I. Kupchak, O. O. Smotr, M. J. Kupchak, Tendencies and problems of implementation of information technologies in the management of university departments, Bulletin of Lviv State University of Life Safety (2013) 28–32. URL: https://journal.ldubgd.edu.ua/index.php/Visnuk/article/view/714.

[28] O. Y. Karabin, Heimifikatsiia v osvitnomu protsesi yak zasib rozvytku molodshykh shkoliariv [Gamification in the educational process as a means of development of primary school children], Pedahohika formuvannia tvorchoi osobystosti u vyshchii i zahalnoosvitnii shkolakh 1 (2019) 44–47. URL: http://web.archive.org/web/20240817225259/http://dspace.tnpu.edu.ua/handle/123456789/14039.

[29] M. Kochengina, O. Koval, The use of the game in the educational process of the first cycle of primary school: a scientific and methodological manual, Kharkiv Academy of Continuing Education, Kharkiv, 2019.

[30] N. V. Kudykina, Theoretical foundations of pedagogical control of primary school children playing activity in extra-curriculum educational process, Dissertation for a doctor degree in pedagogical sciences on specialit y 13.00.01 – general pedagogy and history of pedagogy, Institute of Pedagogy of the Academy of Pedagogical Sciences of Ukraine, Kyiv, 2004. URL: https://nrat.ukrintei.ua/searchdoc/0504U000141/.

[31] Y. Bludova, O. Ilina, Gamemization of the education process in the New Ukrainian School, Aktualni pytannia humanitarnykh nauk 1 (2020) 169–173. URL: http://www.aphn-journal.in.ua/archive/27_2020/part_1/30.pdf. doi:10.24919/2308-4863.1/27.203390.

[32] M. I. Yaremii, O. S. Haliuka, Gamification as a means of developing communicative competence in elementary school students, 2023. URL: https://tinyurl.com/3h9rrp9c.

[33] V. L. Buzko, Y. V. Echkalo, Gamification as a mean of forming of cognitive interest in physics teaching, New computer technology 15 (2017) 171–175. doi:10.55056/nocote.v15i0.660.

[34] K. V. Kiptilyi, Heimifikatsiia pry navchanni informatyky uchniv serednoi shkoly, in: Suchasni informatsiini tekhnolohii ta innovatsiini metodyky navchannia: dosvid, tendentsii, perspektyvy : materialy II mizhnarodnoi naukovo-praktychnoi internet-konferentsii z nahody sviatkuvannia 30-richchia kafedry informatyky ta metodyky yii navchannia (8-9 lystopada 2018 r.), TNPU im. V. Hnatiuka, Ternopil, 2018, pp. 202–204. URL: http://web.archive.org/web/20220320093125/http://dspace.tnpu.edu.ua/handle/123456789/15317.

[35] O. O. Salata, O. F. Trukhan, Gamification as a means of improving the efficiency of the learning process in secondary education institutions, Continuing Professional Education: Theory and Practice 76 (2023) 47–60. URL: https://elibrary.kubg.edu.ua/id/eprint/46774/1/O_SALATA_O_TRUHAN_NPO_3_2023_IPO_KUBG.pdf. doi:10.28925/1609-8595.2023.3.5.

[36] N. M. Fidria, Nova ukrainska shkola: Heimifikatsiia na urokakh heohrafii, 2018. URL: https://super.urok-ua.com/stattya-nova-ukrayinska-shkola-geymifikatsiya-na-urokah-geografiyi/.

[37] M.-B. Ibáñez, Á. Di-Serio, C. Delgado-Kloos, Gamification for Engaging Computer Science Students in Learning Activities: A Case Study, IEEE Transactions on Learning Technologies 7 (2014) 291–301. doi:10.1109/TLT.2014.2329293.

[38] E. Kahu, Framing Student Engagement in Higher Education, Studies in Higher Education 38 (2013) 758–773. doi:10.1080/03075079.2011.598505.

[39] G. Skaskiv, Introduction of gamification technologies in the educational process of higher education institutions, Scientific Journal of the National Pedagogical Dragomanov University : Pedagogical sciences: realities and prospects 83 (2021) 156–161. URL: http://elar.fizmat.tnpu.edu.ua/handle/123456789/1206. doi:10.31392/NPU-nc.series5.2021.83.32.

[40] O. V. Zakharova, A. V. Gruzd, Improving the quality of higher education services through gamification, Scientific works of Kirovograd National Technical University. Economic sciences 32 (2017) 113–122. URL: http://nbuv.gov.ua/UJRN/Npkntu_e_2017_32_13.

[41] R. Duran, J.-M. Rybicki, J. Sorva, A. Hellas, Exploring the Value of Student Self-Evaluation in Introductory Programming, in: Proceedings of the 2019 ACM Conference on International Computing Education Research, ICER '19, Association for Computing Machinery, New York, NY, USA, 2019, p. 121–130. doi:10.1145/3291279.3339407.

[42] S. Mladenović, D. Krpan, M. Mladenović, Using Games to Help Novices Embrace Programming: From Elementary to Higher Education, International Journal of Engineering Education 32 (2016) 1–11. URL: https://www.researchgate.net/publication/291696663.

[43] V. Y. Bugaeva, Gamification as a way of forming active professional behavior of future IT specialists,

Collection of scientific papers “Pedagogy and Psychology” (2017) 129–135. URL: http://nbuv.gov.ua/UJRN/znpkhnpu_ped_2017_56_16.

[44] K. Gama, C. Zimmerle, P. Rossi, Online Hackathons as an Engaging Tool to Promote Group Work in Emergency Remote Learning, in: Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1, ITiCSE ’21, Association for Computing Machinery, New York, NY, USA, 2021, p. 345–351. doi:10.1145/3430665.3456312.

[45] R. Blanco Aguirre, M. Trinidad, M. J. Suárez Cabal, A. Calderón, M. Ruiz, T. González, P. JavierUni, Impact of Gamification Software Testing Education, 2020. URL: https://www.kaggle.com/datasets/agungpambudi/gamification-software-testing-education-analysis.