# Integrated Game-based Learning in an Informatics Secondary Course: Is There a Difference between Girls' and Boys' Achievements?

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Abstract: Informatics subject is a compulsory course for Bulgarian high school students with specialisation in Computer Science, Mathematics, and Natural sciences. The subject starts in 8th grade and in fact it is an introductory course in programming. According to the national syllabus of the subject, teachers can choose one of the following programming languages: C#, Visual Basic or Java. The content of the course is too abstract for the 14 years old students. To reduce the level of abstraction and to motivate the students we implemented integrated game based model for teaching programming. The model is based on usage of educational computer games for introduction of main concepts, experimenting with already developed games, usage of "half baked" tasks and programming of games. Also, game based approach is combined with problem solving, project based and e-learning approaches and technologies. The implementation of integrated game based model was experimented with 126 8th graders at Mathematics and Natural Sciences High School. In this paper we analyse and compare the achievements of the boys and girls that participated in experimental training. Also the achievements of the students from the experimental group are compared with achievements of students from the same school that have not been trained with the discussed approach. This group is used as control group. Boys and girls that have been taught according to the proposed model show the same achievements. The statistically significant difference exists between achievements of girls form experimental and control group. Girls from experimental group demonstrate higher achievements in programming and practical problem solving than girls from control group. Also the boys trained via integrated game based approach have higher results than boys in control group. The obtained results show that the implementation of integrated game-based learning influences the performance of both boys and girls in a positive manner.

## 1 INTRODUCTION

The rapid development in the technological area has directly influenced not only the economy, but also many other areas of everyday life. When it comes to education, many countries have introduced some changes to their school curricula, which allow them to train much needed technologically qualified specialists. Meanwhile another trend is also observed – students' motivation and interest in studying science and technology is constantly dropping. This raises the need of active researching and developing new education models that correspond with the interests and requirements of the contemporary students.

A lot of effort is put into growing young people's interest and abilities to succeed in the area of computer science. Games are seen as tools for introduction of basic programming skills (Gee & Tran, 2015). Educational computer games provide a safe environment, in which students can learn and have fun, while playing.

In the article we present some experimental results from implementing integrated game-based

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learning in Informatics classes. The experimental training was conducted with 8th-graders (14 year old students). We compare the achievements of students trained in integrated game-based learning (IGBL) approach and those that were not trained in the game-based learning (GBL). We focus the comparative studies on the girls' and boys' achievements in both cases – IGBL and non GBL. Students that were trained in IGBL we call experimental group (EG) and those that were not trained in GBL we call control group (KG). In section two we present the current status of education in Computer science in Bulgarian schools. Section three deals with the model of integrated game based learning in Informatics in secondary school. A set of research questions regarding differences in achievements of boys and girls in both groups are outlined in section four. Also, in section five comparative analysis and results are discussed.

# 2 EDUCATION IN INFORMATICS IN BULGARIAN SECONDARY SCHOOLS AND HIGH SCHOOLS

Bulgarian secondary schools have a long history in education in Informatics. (Assenova, Nikolov, Stanchev, & Koleva, 1996), (Azalov, 2019). First courses in programming have been launched in late 1960s in some high schools with intensive study of mathematics. From school year 1986/1987 on Informatics has been involved as a compulsory course in all upper secondary schools. "Bulgaria became the fourth country in the world to introduce Informatics as a compulsory subject." (Garov & Tabakova-Komsalova, 2017) During the years several changes in number of classes per week and subject content have been done.

Nowadays in Bulgarian schools there are two subjects related to computer science – Information Technology and Informatics. Information technology (IT) is a compulsory subject for students from 5th grade till 10th grade. Informatics is a compulsory subject for students in 8th grade from 2017/2018 school year on and in 9th and 10th grades up until 2016/2017 school year. The subject Informatics is focused on algorithms and programming languages and data structures. The subject Information technology deals with development of digital competences using different software. It covers topics like computer systems, operating systems, word-processing, computer graphics, spreadsheets, computer presentations, internet communication, networks, internet safety, copyrights etc.

Currently programming is being taught in the compulsory courses Informatics (in high school) and Computer modelling (in primary school). Moreover, every school can provide elective or extracurricular courses related to the development of programming skills. As of 2020 the Ministry of education has started a new school programme called "Education for tomorrow day". It is directed towards developing and increasing the digital skills of the students in the secondary schools in Bulgaria.

As it was already mentioned, the school subject Informatics is a compulsory course in 8th grade for all high schools with specialisation in mathematics, computer science, natural sciences, economics and entrepreneurship.

The compulsory course Informatics for 8th grade is an introductory course in programming; it is planned for 72 hours (2 hours per week) and consists of four modules according to the national syllabus (Ministry of Education and Science, 2017):

- "Fundamentals of Informatics" module includes basic terms in Informatics/Computer Science, computer representation of the numbers, algorithms and programming languages.
- "Visual Programming Environments" module with topics in application of integrated development environment (IDE) for visual programming, basic stages in designing and running of computer program, and designing of graphical user interface.
- "Programming" module includes some classical topics from introduction in programming courses like data types, programming structures for implementation of branching and looping algorithms, data structures like one-dimensional array, program testing and verification.
- "Development of a Software Project" module includes simplified basic topics from software engineering area – analysis of requirements, design, implementation, verification and testing of computer program, preparing of documentation, team working and project presentation.

According to the syllabus, teachers can choose C#, Visual Basic, or Java as a programming language, with an appropriate IDE, to implement the above mentioned modules.

The content of the course is too complex, abstract and difficult for students in 8th grade. Therefore, the teacher needs to apply different approaches and techniques to engage and motivate students more effectively and as a result to increase their performance. To achieve this goal, a model for an integrated game-based approach was developed and applied.

## 3 INTEGRATED GAME-BASED MODEL FOR TEACHING INFORMACTICS IN SECONDARY SCHOOL

The proposed model is based on the integration of game-based learning, project-based learning, problem-solving, and cross curricular links. The course in programming is based on C# in Microsoft Visual Studio 2017.

Game-based tasks gain more and more popularity in computer science education, where the game design is seen as a tool for introduction of basic programming skills (Gee & Tran, 2015) (Sung, 2009), (Morrison & A. Preston, 2009). Game-based learning is a possible solution to the problem with the main difficulties students meet when studying programming (Shabalina, Malliarakis, Tomos, & Mozelius, 2017). Games motivate students to actively participate in the educational process (Malliarakis, Satratzemi, & Xinogalos, 2014) and to develop problem-solving skills (Maraffi, Sacerdoti, & Paris, 2017).

In the papers of (Wolz, Barnes, & Parberry, 2006) (Shabalina, Malliarakis, Tomos, & Mozelius, 2017) the authors suggest two approaches for inclusion of digital games in computer science curriculum.

In the current study the game-based approach in Informatics classes is implemented by conducting the following stages:

- Using existing educational computer games (ECG):
  - for knowledge and skills acquiring, motivation of learning activities, development of algorithmic thinking;
  - for experimenting with existing ECG to inquire of game rules, interface elements and their properties and events;
- Designing and developing ECG including mathematical model of the game, design of graphical user interface (GUI); coding, testing and verifying.

The games and tasks are related to well-known games like “Rock, paper, scissors”, “Guess the number”; real-live everyday activities; cross curricular content with maths, physics, entrepreneurship, biology, etc.; quest-based games related to different school subjects.

One example of a game that is used in the beginning of the course for acquiring and assessment of knowledge about numeral systems is the game NS (Numeral systems) Fig.1.

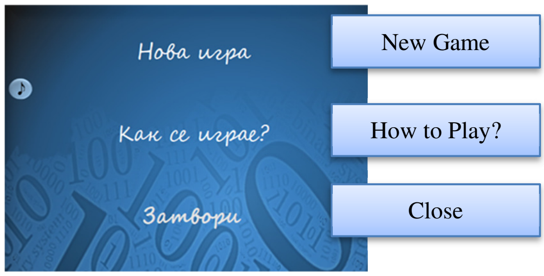


Figure 1: Start of the game NS.

The learning objectives of the game are related to the transformation of numbers from one numeral system to another, and to the addition and subtraction in binary numeral system. The game enables to be implemented cross curricular relationships between informatics, mathematics, and information technology.

The NS game consists of 16 levels – four levels for numeral systems with bases 2, 3, 4 and 5. The items in every level are four and are with an increasing level of difficulty. All tasks use random numbers in decimal numeral system: for level one the number is in [0;63], for level two - [64;127], for level three - [128;192], and for level four - [193;255]. In case of wrong answer a new item with the same difficulty level appears.

If the player has four errors, the game is over.

**Level one** is directed to the transformation from decimal to binary numeral system. On the screen are shown ten buttons (Fig. 2.) labeled with either 0 or 1. When the player is clicking on the button, the label is changed from 0 to 1 and from 1 to 0. Using the buttons the player has to obtain the binary representation of the decimal number in the task. As a hint over every button is written the value of two to the corresponding power.

**Level two** (Fig. 3.) is purposed for transformation of a number from binary to decimal numeral system. In this item the player should write the decimal number in the text box.

**Level three** (Fig. 4.) is related to addition in binary system.

**Level four** (Fig. 5.) is related to subtraction in binary system. The next levels are similar but the base of the numeral system is higher.

For each right answer, the player obtains one point. Also, the game takes into account the time. This could be used as an additional criteria in case of knowledge evaluation.

The game is developed using C# in MS Visual Studio 2017.

The model of the game is used in the topics:

- "Design of GUI" – for creation of start screen of the game;
- "Programming construction for branching and loops".

The syllabus for 8th grade does not contain topics related to processing of more forms. Therefore the students do not join all game levels in one form.

Also the course is supported in the e-learning environment Moodle, where students can find additional learning content, examples, can upload home works and projects, make self-assessment and assessment.

At the end of the course students works on group projects. In the frame of the final project students have to develop game, prepare documentation and present it. The projects are divided in two main groups: Development of game from scratch and development of game with a "template" given in the tutorials at web site https://www.mooict.com/ .

In the first type of projects students have to: propose game plot; model GUI; find pictures for graphical design; develop appropriate algorithms; code the game; prepare documentation and project presentation.

In the second type of projects students have to: develop a game following instructions in the tutorial (it is not possible to use "copy-paste"); translate from English to Bulgarian all directions for project development suggested in the tutorial and to add images from their own project; prepare project presentation.

## 4 EMPIRICAL STUDY OF BOYS' AND GIRLS' ACHIVEMENTS

The model was empirically tested with 126 students in 8th grade from High School for Math and Natural Science, Blagoevgrad. We obtained data from a final assessment – Paper based test and Practical task, from 68 students in EG and 58 students in CG. Data was analysed using RStudio.

The test consists of 17 items, of them items with multiple choice are 13, open answer – 4. The tasks with open answer require finding errors in the code, to predict results in given code. The practical task requires students to describe steps to solve task, plan user interface, name the objects in the form and describe purpose of events and properties of the objects in the form.

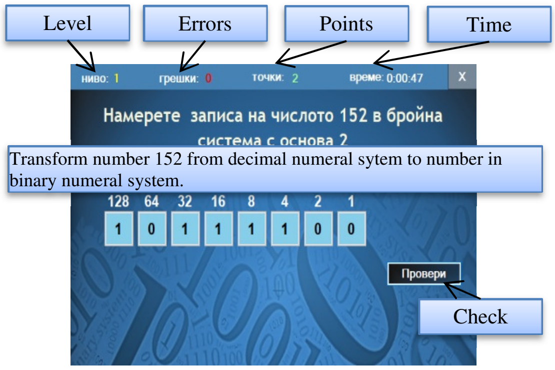


Figure 2: Level one.

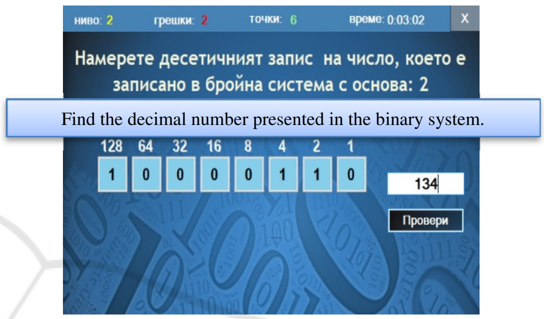


Figure 3: Level two.

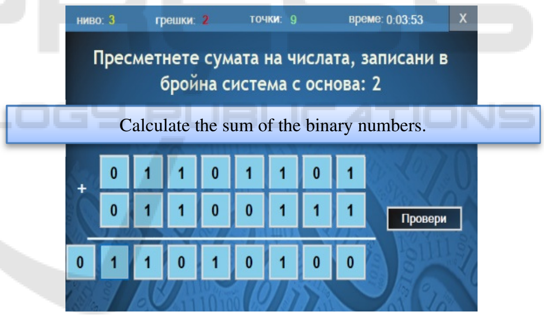


Figure 4: Level tree.

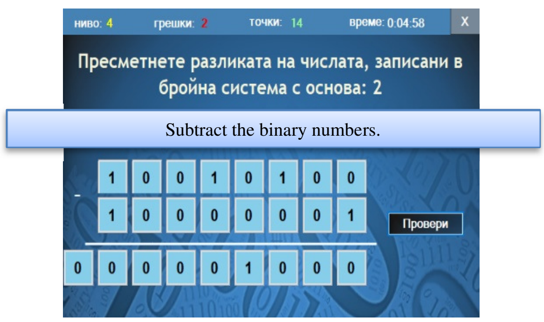


Figure 5: Level four.

We set the following research questions:

RQ1. Is there a statistically significant difference between the results from Test in CG and EG?

RQ2. Is there a statistically significant difference between the results from Practical task in CG and EG?

RQ3. Is there a statistically significant difference between boys' and girls' results from Test in EG?

RQ4. Is there a statistically significant difference between boys' and girls' results from Practical task in EG?

RQ5. Is there a statistically significant difference between boys' and girls' results from Test in CG?

RQ6. Is there a statistically significant difference between boys' and girls' results from Practical task in CG?

RQ7. Is there a statistically significant difference between girls' results from Test in CG and EG?

RQ8. Is there a statistically significant difference between girls' results from Practical task in CG and EG?

RQ9. Is there a statistically significant difference between boys' results from Test in CG and EG?

RQ10. Is there a statistically significant difference between boys' results from Practical task in CG and EG?

We used the following statistical methods:

- Descriptive statistics, including mean, median, mode, standard deviation and variance. As in R's standard library there is no function for computing mode, the following method was implemented for the purpose:

```
getMode <- function(values)
    {uniqueValues <- unique(values)
    uniqueValues[which.max(tabulate
    (match(values, uniqueValues)))]
    }
```

- Determining the type of the distributions of the analyzed samples. Given that knowledge we can choose a suitable statistical test for sample comparison. A Shapiro-Wilcoxon test with null hypothesis "The distribution is normal", alternative hypothesis "The distribution is not normal" and level of significance p=0.05 is applied.
- The already set research questions require comparison of independent sample. If both samples are normally distributed, we conduct one-tailed t-test for comparison of the means. If at least one of the samples is not normally distributed, we conduct nonparametric Mann-Whitney-Wilcoxon test.

For the purpose of the study the data is divided into separate R data frames, as follows:

- **datasetEG** – data about all students in EG;
- **datasetCG** – data about all students in CG;
- **datasetEGFemale** – data about girls in EG;
- **datasetEGMale** – data about boys in EG;
- **datasetCGFemale** – data about girls in CG;
- **datasetCGMale** – data about boys in CG.

## 5 RESULTS

Descriptive statistics of all analysed groups for the achievements from Test are presented in table 1, and from Practical task in table 2.

Table 1: Descriptive statistics for achievements from Test.

| **Sample** | **Mean** | **Median** | **Mode** | **Standard deviation** | **Variation** |
|---|---|---|---|---|---|
| datasetEG $TestPoints | 24.88 | 25 | 23 | 5.532089 | 30.60401 |
| datasetCG $TestPoints | 21.14 | 21 | 21 | 7.651887 | 58.55138 |
| datasetEGFemale $TestPoints | 23.94 | 24 | 23 | 5.77491 | 33.34958 |
| datasetEGMale $TestPoints | 25.85 | 27.5 | 28 | 5.176476 | 26.7959 |
| datasetCGFemale $TestPoints | 20.40 | 21 | 18 | 8.087308 | 65.40456 |
| datasetCGMale $TestPoints | 21.8 | 21 | 21 | 7.312719 | 53.47586 |

Table 2: Descriptive statistics for achievements from Practical task.

| **Sample** | **Mean** | **Median** | **Mode** | **Standard deviation** | **Variation** |
|---|---|---|---|---|---|
| datasetEG$Practical TaskPoints | 6.45 | 6 | 14 | 4.98095 | 24.8098 |
| datasetCG$Practical TaskPoints | 2.86 | 0 | 0 | 4.87500 | 23.7657 |
| datasetEGFemale$P racticalTaskPoints | 5.6 | 5 | 0 | 4.8215 | 23.2471 |
| datasetEGMale$Pra cticalTaskPoints | 7.32 | 6.5 | 14 | 5.06156 | 25.6194 |
| datasetCGFemale$P racticalTaskPoints | 2.26 | 0 | 0 | 4.39923 | 19.3533 |
| datasetCGMale$Pra cticalTaskPoints | 3.4 | 0.5 | 0 | 5.28237 | 27.9035 |

For determining the type of the distribution of each sample a Shapiro-Wilcoxon test with null hypothesis "The distribution is normal", alternative hypothesis "The distribution is not normal" and level of significance p=0.05 is conducted. The built-in function shapiro.test(values) is used.

Given p >= 0.05 we accept the null hypothesis, otherwise we discard the null hypothesis and accept the alternative. Table 3 and Table 4 show the results from conducting the test on the studied data and the conclusions whether the given sample is normally distributed.

Table 3: Type of distribution of test points.

| Sample | p-value | Normal distribution |
|---|---|---|
| datasetEG$TestPoints | 0.177 | Yes |
| datasetCG$TestPoints | 0.045 | No |
| datasetEGFemale$TestPoints | 0.2381 | Yes |
| datasetEGMale$TestPoints | 0.04586 | No |
| datasetCGFemale$TestPoints | 0.2149 | Yes |
| datasetCGMale$TestPoints | 0.4601 | Yes |

Table 4:Type of distribution of practical task points.

| Sample | p-value | Normal distribution |
|---|---|---|
| datasetEG$PracticalTaskPoints | 3.016E-05 | No |
| datasetCG$PracticalTaskPoints | 7.093E-11 | No |
| datasetEGFemale$PracticalTaskPoints | 0.002242 | No |
| datasetEGMale$PracticalTaskPoints | 0.003763 | No |
| datasetCGFemale$PracticalTaskPoints | 1.09E-07 | No |
| datasetCGMale$PracticalTaskPoints | 3.699E-07 | No |

RQ1. Is there a statistically significant difference between the results from Test in CG and EG?

The data distribution in EG is normal, but in CG it is not, so we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

We use the built-in function wilcox.test(). The results are: W = 1287, p-value = 0.0008587.

We can conclude that there is a statistically significant difference between the two samples. The students in EG show higher results (median = 25) in comparison to the students in CG (median = 21).

RQ2. Is there a statistically significant difference between the results from Practical task in CG and EG?

Both distributions are not normal. In that case we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 1007, p-value = 1.567E-06

Accordingly there is a statistically significant difference between the two samples. The students in EG show higher results (median = 6) in comparison to the students in CG (median = 0).

RQ3. Is there a statistically significant difference between boys' and girls' results from Test in EG?

The distribution of girls' results from Test is normal, but that of boys' results is not, therefore we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 450.5, p-value = 0.08306

We can conclude that there is no statistically significant difference between the two samples. Both boys and girls that have been taught according to the proposed model show the same results from Test.

RQ4. Is there a statistically significant difference between boys' and girls' results from Practical task in EG?

Both distributions are not normal, therefore we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 475, p-value = 0.1489

We can conclude that there is no statistically significant difference between the two samples. Both boys and girls that have been taught according to the proposed model show the same results from Practical task.

RQ5. Is there a statistically significant difference between boys' and girls' results from Test in CG?

Both distributions are normal, so we conduct a one-tailed t-test for mean comparison. We use the built-in function t.test().

The results are: t = -0.67912, df = 52.74, p-value = 0.25

We can conclude that there is no statistically significant difference between means of Test results of boys and girls in CG. Both boys and girls achieve equal results.

RQ6. Is there a statistically significant difference between boys' and girls' results from Practical task in CG?

Both distributions are not normal, therefore we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 348, p-value = 0.3138

We can conclude that there is no statistically significant difference between means of Practical task results of boys and girls in CG.

RQ7. Is there a statistically significant difference between girls' results from Test in CG and EG?

Both distributions are normal, so we conduct a one-tailed t-test for mean comparison.

The results are: t = -1.9244, df = 45.137, p-value = 0.03031

Accordingly there is a statistically significant difference between the two samples. Girls from EG score higher (mean = 23.94286) in Test than girls in CG (mean = 20.40741).

RQ8. Is there a statistically significant difference between girls' results from Practical task in CG and EG?

Both distributions are not normal, therefore we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 230.5, p-value = 0.0004194

Accordingly there is a statistically significant difference between the two samples. Girls in EG score higher in Practical task than girls in CG.

RQ9. Is there a statistically significant difference between boys' results from Test in CG and EG?

The distribution in CG is normal, but that in EG is not, so we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 324, p-value = 0.01238

We can conclude that there is a statistically significant difference between the two samples.

RQ10. Is there a statistically significant difference between boys' results from Practical task in CG and EG?

Both distributions are not normal. Therefore we conduct the nonparametric Mann-Whitney-Wilcoxon test for comparison of independent samples.

The results are: W = 266.5, p-value = 0.0008828

Accordingly there is a statistically significant difference between the two samples.

## 5 CONCLUSIONS

The article discusses a model for teaching programming to students in 8$^{th}$ grade (14-year olds). The model lies on the integration of game-based learning with project-based learning, problem-based learning, cross curricular links and e-learning technologies.

The results from the conducted experimental study show that the proposed model allows both girls and boys to accomplish higher achievements. Boys and girls that have been taught according to the proposed model show the same achievements. The statistical significant difference exists between achievements of girls form experimental and control group. Girls from experimental group demonstrate higher achievements in programming and practical problem solving than girls form control group. Also the boys trained via integrated game based approach have higher results than boys in control group. The obtained results show that the implementation of integrated game-based learning influences the performance of both boys and girls in a positive manner.

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