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Online self-learning

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Abstract. In this paper four short sessions are reviewed in the theme of introductory programming. The sessions were performed in four different student groups from the age twelve to seventeen in two different schools. The paper summarizes important input and output properties of the groups, like the preliminary studies of Informatics and the grades in both Informatics and Mathematics – if available – also the results of the learning process during the sessions. The focus is on the skills of programming and self-learning, and the differences of it in respect to the age, the gender and the preliminary studies.

Introduction

In this paper the experiences of four short programming sessions performed among elementary and middle school students presented. During the sessions the Python, a high-level programming language, was taught with the help of an online game, named CodeCombat [1] The study has been realised in the frame of the "Debrecen Venture Catapult" project by the research group named "Developing skills for engineering and innovation", at the Faculty of Engineering of the University of Debrecen. During the past several months four introductory programming sessions were performed with the participation of 43 students, in 4 different groups. The primary aim of the sessions was to motivate the students to choose engineering as a major field of their future studies. Furthermore, secondary reason was to find out how the students relate to the novel, unusual learning and teaching methods, how they relate to the skill of programming to be acquired, and examine the correlation between the student preliminary knowledge, age and gender and the efficiency in the CodeCombat. Preliminary knowledge of Computer Science was checked from the National Core Curriculum of Hungary (NCC) and the syllabus of the particular classes. Former grades in Informatics and Mathematics were collected from the teachers. The paper is organized as follows. In section 1 a brief introduction is given to the concept of programming and the competencies necessary to learn it. In Section 2 a brief insight is given about the online self-learning methods. Section 3 is about the research methodology and the structure of the sessions. In Section 4 the results of the research are summarized, Section 5 draws conclusions.

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1. Theoretical background

1.1. The concept of programming

In the following some of the many definitions of programming is listed chronologically for the understanding what is the skill the students will have some practice after the sessions. In 1950 Hartree said that "the process of preparing a calculation for a machine can be broken down into two parts, 'programming' and 'coding'. Programming is the process of drawing up the schedule of the sequence of individual operations required to carry out the calculation." [2]. In 1957 MCCracken define programming as "programming … is basically a process of translating from the language convenient to human beings to the language convenient to the computer" [3]. In 1958 Booth stated that "the process of organizing a calculation can be divided into two parts – the mathematical formulation and the actual programming … translating … into the language of the computing machine" [4]. In 1985 Naur changed the approach, his definition is the next "programming is to have the programmers build a theory of the way the matters at hand may be supported by the execution of a program" [5]. The definition written by Blackwell in 2002 is that programming is "to write a sequence of coded instructions fed into a computer … to arrange data in a suitable form so that it can be processed by a computer … to feed a program into a computer" [6]. In 2017 Bell created a definition which is used in this paper. Based on his paper programming or coding – the two words are used as synonyms in that particular paper – "is taking the algorithm and converting it to a working program" [7], where the algorithm is "the particular method used to find a solution to the problem.", the program is "a particular implementation of an algorithm in a chosen language" [7]. If you run a web search on the line "What is programming?", you will get many similar results like the following. Programming is „the action or process of writing computer programs." [8], or "the planning, scheduling, or performing of a program" [9], or "is the implementation of logic to facilitate specified computing operations and functionality." [10] In this paper when the concept of programming is used it refers to Bell's definition.

1.2. Informatics competencies

As it can be seen from the above quoted definitions the skill of programming, is a complex task and it requires many different competencies to learn and different way of thinking. That new thinking way is referred as "programming thinking" or "computational thinking" in the related scientific literature, and what is meant by it is "as understanding of concepts, but also as methods and study techniques necessary when learning to program" [11] according to Eckerdal. By Nouri, another source it "is a set of general problem-solving skills based on computer science that allows computers to be used effectively in the process of problem solving" [12]. Most of the definitions declare that programming is the way how the man-computer communication is realized, so it can be stated that learn to code is like learning a foreign language. It is demonstrated by several studies that there are cognitive benefits of learning another language, the advantages are "bigger brains, better memories, more creative thinking, better problem solvers, switch between tasks much faster or handle many more tasks at once". [13] In the related literature [14], [15] the following competencies were listed as a requirements of being a good programmer. All the competencies are defined in the following list.

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- Algorithmic thinking "is a way of getting to a solution through the clear definition of the steps needed – nothing happens by magic. The power of algorithmic thinking is that it allows solutions to be automated." [16]. Or "is somehow a pool of abilities that are connected to constructing and understanding algorithms, the ability to analyse given problems, … to specify a problem precisely, … to find the basic actions that are adequate to the given problem, … to construct a correct algorithm to a given problem using the basic actions, … to think about all possible special and normal cases of a problem, … to improve the efficiency of an algorithm" [17].
- Analytical thinking "is the ability to scrutinize and break down facts and thoughts into their strengths and weaknesses. Developing the capacity to think in a thoughtful, discerning way, to solve problems, analyse data, and recall and use information." [18].
- Logical thinking "is the process in which one uses reasoning consistently to come to a conclusion. Problems or situations that involve logical thinking call for structure, for relationships between facts, and for chains of reasoning that make sense." [19].
- Abstract thinking is the ability "to relate physically distinct concepts through their common qualities, which allows us to translate problems from one domain into another" [20].
- Patience and creativity do not have to be defined.

2. Online self-learning

In the related scientific literature, the concept of the online self-learning is defined in several different ways. A few of the available definitions are mentioned below. Khan says in [21] , that online learning is the set of those instruction methods, which provide learning environment for remote students through the internet. Carliner's definition in [22] is different in the manner of the delivery media only. It defines online learning is as the set of all learning resources which provided by a computer. However, Oblinger in [23] says that online learning contains only those learning methods, which take place fully online. Bates definition in [24] and in [25] is the next „Online learning is any form of learning conducted partly or wholly over the Internet." As a conclusion it can be said that the online self-learning is such a term, which refers to numerous instructional environments and approaches. The options are wide, included but not limited to online courses, coding games, video tutorials, blogs or mobile applications. In this research an online coding game the CodeCombat is used as the tool of online self-learning.

3. Methodology of the research

3.1. Participants and circumstances of the research

Four small groups were involved in the research, with an average 11 students per group. 33 students attended to Debreceni Árpád Vezér Primary School (DÁV) in the time of the examination. The beforementioned primary school is located in Debrecen, which is the second largest city of Hungary and this school usually is among the top 5 primary schools in the abovementioned town [26]. The average grades are 4.2 and 4.8 in Informatics and Mathematics respectively. The educational program of the DÁV

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differs a little bit from the NCC, namely the students have an extra lesson in Mathematics on the 5th,6th and the 8th year and an extra half lesson in the 7th year. In Informatics according to the NCC there is a single lesson on the year 6, 7 and 8, but in the DÁV an extra lesson on the 5th year is added. Only a tiny part of the Informatics classes is about programming, based on the educational program of DÁV [27] 4, 10, 10, 10 lessons are provided to learn about problem solving with Informatics tools in the 5th, 6th, 7th and 8th year respectively. Three groups were examined in DÁV which are the following:

Group	Year	Number	Male/Female	Session
A	6	11	6/5	June 2018
B	7	11	4/7	June 2019
C	8	13	5/8	May 2018

Properties of groups of the Debreceni Árpád Vezér Primary School

The other 10 students attended to the Medgyessy Ferenc High School and Art School (MF), which located in Debrecen too. MF is 9th from 11 in the school ranking among the 4-grade high schools in Debrecen, and the 1st from 3 among art schools based on the National Competence Test [28]. In the MF 3 Mathematics lessons are compulsory for the 9th,10th,11th and the 12th year students, and 1 lesson in the year 9 and 10 from Informatics. The number of lessons in Mathematics equals to the minimum of recommended in the NCC 9th ,10th ,11th and 12th year. The minimum recommended number of lessons in Informatics is 1 in all the four years of high schools, in MF the students have 1 lesson in the 9th and 10th only. Only a tiny part of the IT classes is about programming, based on the educational program of MF [29] 10 classes are provided to learn about problem solving with IT tools in the 9th and 10th year too. The chosen class in MF has a specialization of Art, the students' major is dance, sculptor or painter.

Group	Year	Number	Male/Female	Session
D	11	10	2/8	June 2019

Properties of the group of the Medgyessy Ferenc High School and Art School

In the following tables information about the students – involved in the experiment – displayed by groups.

Group A	Grade in Mathematics	Grade in Informatics	Male/Female	Total Levels	Total playtime
1.	4	5	M	19	60
2.	3	3	M	7	43
3.	4	4	M	10	41
4.	5	5	M	11	39
5.	5	5	M	16	60
6.	2	4	M	16	60

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7.	5	5	F	4	40
8.	5	5	F	7	23
9.	3	4	F	5	42
10.	5	5	F	3	41
11.	5	5	F	12	60

Properties of group A

Group B	Grade in Mathematics	Grade in Informatics	Male/Female	Total Levels	Total playtime
1.	5	5	M	22	120
2.	4	5	M	13	29
3.	5	5	M	13	22
4.	5	5	M	18	60
5.	5	5	F	2	7
6.	5	4	F	1	5
7.	4	4	F	3	10
8.	4	4	F	3	26
9.	3	4	F	0	0
10.	4	5	F	0	0
11.	4	4	F	0	0

Properties of group B

Group C	Grade in Mathematics	Grade in Informatics	Male/Female	Total Levels	Total playtime
1.	4	4	M	10	27
2.	3	5	M	15	31
3.	3	4	M	2	14
4.	5	5	M	10	21
5.	5	5	M	4	12
6.	3	4	F	10	28

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7.	2	3	F	6	19
8.	4	4	F	10	29
9.	5	5	F	10	31
10.	5	5	F	9	28
11.	3	4	F	10	25
12.	4	5	F	13	30
13.	4	5	F	10	26

Properties of group C

Group D	Grade in Mathematics	Grade in Informatics	Male/Female	Total Levels	Total playtime
1.	3	-	M	8	26
2.	5	-	M	16	30
3.	2	-	F	7	17
4.	2	-	F	0	0
5.	2	-	F	1	1
6.	4	-	F	16	33
7.	3	-	F	12	24
8.	0	-	F	12	30
9.	4	-	F	9	27
10.	2	-	F	1	2

Properties of group D

3.2. The online self-learning tool

During the sessions the CodeCombat [1] an online game-based computer science program is used. Several different courses are available in the theme of Python, JavaScript, HTML and CSS. A hero is controlled and guided to solve increasingly difficult tasks by the student through source code of the chosen programming language in this strategy game. In the sessions of the research the Python high-level programming language is chosen as the language of the course by the teacher. The user interface provides a very handful toolset to students, who can write a clean and correct code from the first line, they ever code. An immediate interaction with every written line is provided, error messages and hints help the students solve the problems. “Students type real Python and JavaScript while playing games that encourage trial-and-error, critical thinking, and creativity. Students then apply the coding skills

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they've learned by developing their own games and websites in project-based courses." [1] CodeCombat allows teachers to supervise their students activity and progress, while the students learn in their own pace. "CodeCombat equips teachers with the training, instructional resources, and dedicated support to feel confident and successful in the classroom." [1] Figure 2. and Figure 3. shows two screenshots of CodeCombat.

Figure 1. Screenshot of CodeCombat [1]

Figure 2. Screenshot of CodeCombat [1]

3.3. The session

The sessions start with an informal conversation about the students' experiences in programming and online strategy games, then it continues with an introduction to programming languages. The basic concepts of the Python – like the programming language, program code, object, comment, control statements, loops and conditional statements for example if-else – are explained by the lecturer. Briefly the rules of the CodeCombat is explained too and a registration is made together. That two parts of the

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sessions lasts only 10-15 minutes. The next part is the self-learning part, which lasts usually 25-50 minutes. The length of that part is depending on the age of the groups and the time available. The students always excited when it turns out that the task what they have to perform is playing on the computer. Usually they find the game interesting and challenging and they are motivated because of the competitive situation. If the students get stuck in solving the problems, the lecturer is there to help them. At the end of the sessions a short time is provided to learn the opinion of the students about the CodeCombat and the session. The students are encouraged to continue the course at home.

4. Results

In this section the results of the research are summarized. Grades of Mathematics and Informatics at the time of the sessions are collected from the teachers of the groups. CodeCombat provides information about the self-learning process, for example number of the successfully performed levels or amount of the total playtime. The above-mentioned properties of the participants are displayed in Table 3, 4, 5, and 6. The total number of the successfully performed levels is the base property, the change of that is examined depending on the students' grades, age or gender. The following list contains the questions, which try to be answered by this research.

1) Is there any connection between the grade in Mathematics and the total number of successfully performed levels in the game?
2) Is there any connection between the grade in Informatics and the total number of successfully performed levels in the game?
3) Is there any connection of the age of the students and the total number of successfully performed level levels in the game?
4) Is there any connection of the gender of the students and the total number of successfully performed levels in the game?

In the individual groups there was no sense to examine the summarized results, because of the small number of students.

To understand the connection between the grades in Mathematics and the amount of the success in the self-learning method in programming – which is measured by the total number of successfully performed levels (henceforth Total Levels) in CodeCombat– a group of 43 students were examined as a sample. The results confirm the assumption, that the arithmetical mean of the Total Levels is proportional to the grades in Mathematics, so it can be cautiously stated that better grades in Mathematics mean greater success in the self-learning process of programming.

To answer the second question the same examination was carried out but using a sample of 33 students. Result showed the same as in Mathematics, so it can be cautiously stated too, that better grades of Informatics mean greater success in the self-learning process of programming. However, it has to be noted, that in all cases the standard deviation is high, which indicates that the statements made above about the proportions are not absolutely clear. The results of the beforementioned examination are displayed in Figure 3. and Figure 4.

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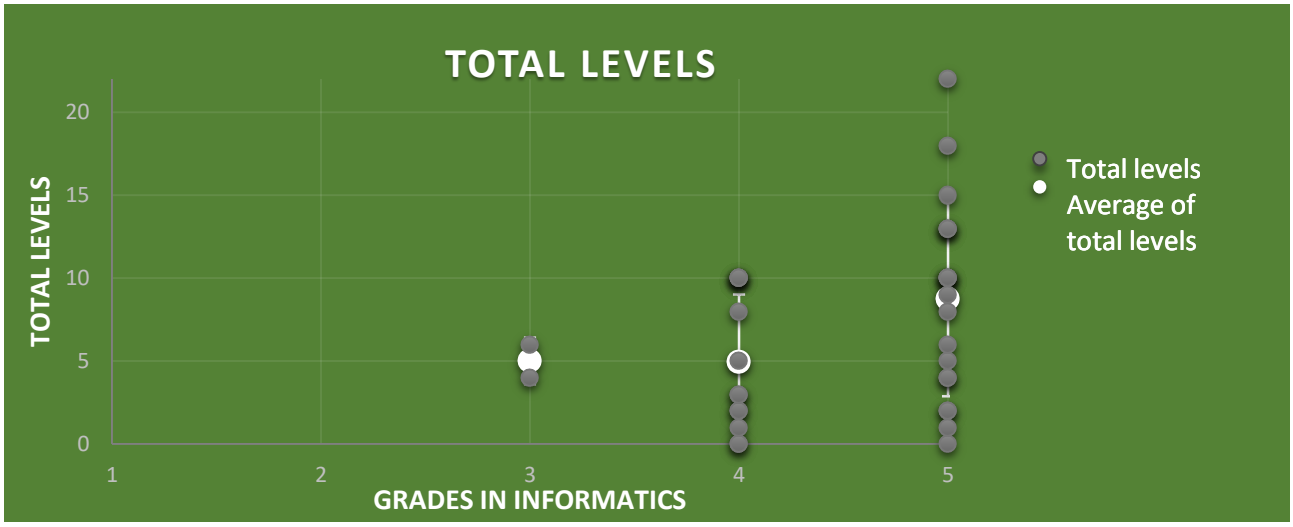

Figure 3. Total levels over Informatics Group A, B and C

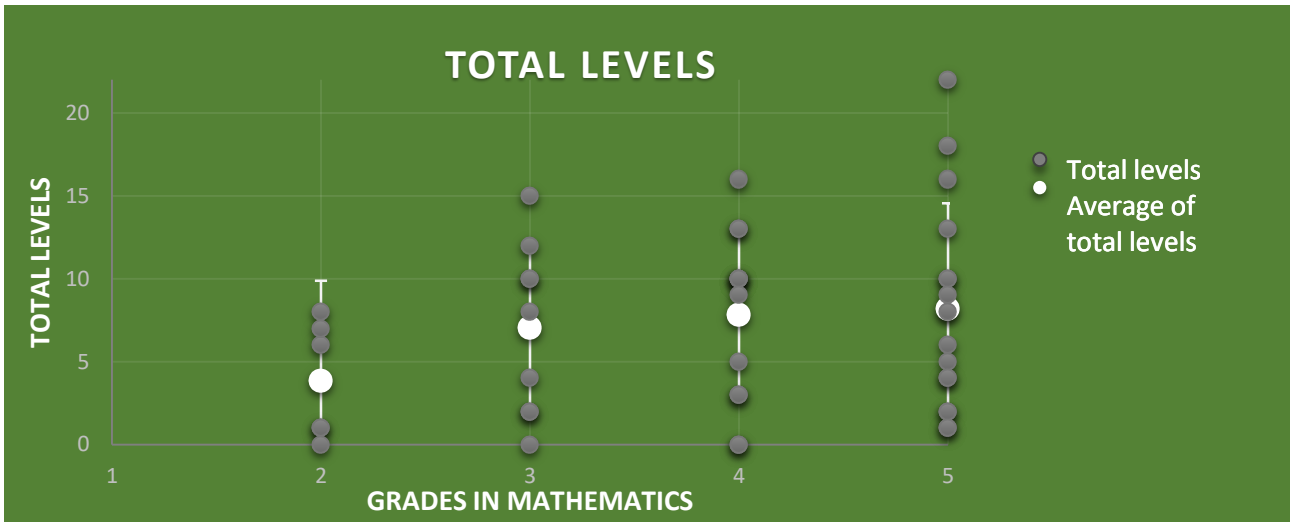

Figure 4. Total levels over Mathematics Group A, B, C and D

In the experiment both male and female students were involved. Before the experiment the hypothesis was raised that the male students perform better, than the female ones. The experiment was performed on 17 male and 28 female students. Figure 5. displays the connected data. It can be seen that the average Total Level in the case of male students is higher, than the one in the case of the female ones which verifies our hypothesis. Although the type of the classes and the number of the Mathematics or Informatics lessons or the age was not taken into consideration when the results were collected

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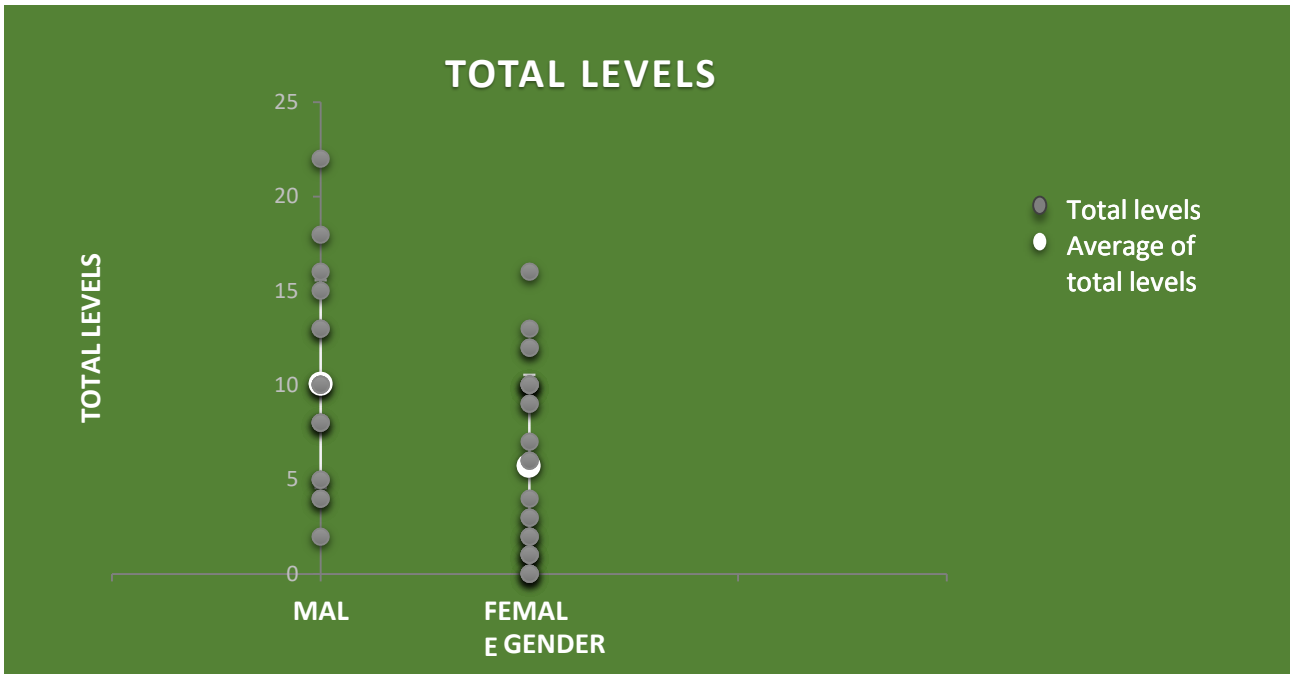

Figure 5. Total levels over Gender Group A, B, C and D

The results were examined in the context of the age too. The initial assumption was, that the older students perform better than the younger ones. After the properties were collected and the suitable quantities were calculated, the only conclusion what can be drawn is, that the students in the 6th grade perform significantly worse than the other ones. Otherwise there is no connection between the age and the performance in the CodeCombat. Results shown in Figure 6.

Figure 6. Total levels over Year Group A, B, C and D

5. Conclusion

Three of the beforehand raised hypotheses were verified with the research among 43 students, but all of it have to be considered cautiously, because of the small amount of the involved students. As a future

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work it would be practical to make a research on a much wider and more heterogeneous thus a more representative sample of students.

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