Establishing Cross-Curricular Connections Through Python Programming in Computer Modeling Education

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Abstract – **In the present paper, the possibilities of making cross-curricular connections through Python programming in computer modeling education are explored. For this purpose, sample projects are systematized according to the study subjects – mathematics, history, geography, human and nature. Their designation is to contribute to the consolidation of certain knowledge and skills, both in terms of Python programming and in the relevant other subject. Concrete implemented projects are represented, different variants of them are discussed, and their accessibility is ensured for their future reuse for educational purposes. As a result, they could be directly used to apply a project-based teaching approach in learning relevant topics from the study material.**

Keywords – **Cross-curricular connections, Python programming, computer modeling learning.**

1. Introduction

The evolution of the information and communication technologies strives to meet the needs of modern society.

On the one hand, these demands include providing opportunities for people with special needs to learn and develop in various fields, including those related to programming [1], [2]. Alternatively, there is a need to enhance the digital competences of students at an earlier stage and in a more comprehensive manner. In this regard, from the school year 2018/2019, a new subject "Computer modeling" is introduced in the educational system in Bulgaria for the 3rd and 4th grades. Computer modeling learning at the primary education is aimed at acquisition of initial knowledge, skills and attitudes related to building the digital literacy of students by creating computer models of known objects, processes and phenomena, and experimenting with them. The aim of incorporating the topics included in the program [3] is to foster the development of mathematical skills, logical reasoning, and creative thinking. The students use software programs through which they create tests, puzzles, games and control robotic devices [4].

In order to continue and upgrade the study of thematic related to computer modeling after the 4th grade, from the school year 2021/2022, the subject "Information Technologies" in the lower secondary education stage is transformed to "Computer Modeling and Information Technologies". The 6th grade curriculum [5] covers the transition from a block programming language to a scripting text language (such as Python, JavaScript, etc.); implementing animation with the means of a scripting text language. The study conducted among the textbooks for the 6th grade from different publishers (Prosveta, Siela, Domino, Klett, etc.) establish that the majority are based on Python as a modern fast-growing language for text programming [6], [7], [8].

The relevance of the implementation of cross-curricular connections through the consideration and solution of tasks whose content is related to other school subjects stems from the need to increase the digital competence of students in various fields in the conditions of the modern digital society.

This approach allows influencing student motivation. Increasing the trainees' interest in studying the learning material through its application in solving practice-oriented problems would in turn improve learning outcomes. In order to contribute to support this process, in the present work, the possibilities of making cross-curricular connections through Python programming in the "Computer Modeling" module in the 6th grade, studied by Bulgarian students, are investigated.

2. Related Work

In recent years, the programming is added to the curriculum of school education in various countries [9]. In 2016, a new curriculum for grades 1–9 is adopted in Finland, which introduces digital competence (including programming) by integrating it into other school subjects [10]. Since 2018, computer science is added as a subject in Irish secondary schools as a pilot scheme [11], [12]. Vinnervik (2022) [13] analyzes the problems that arose as a result of the inclusion of programming as a new content in Swedish school education after a curriculum reform officially adopted in 2018 in Sweden. The need for cross-curricular cooperation in teaching programming and other subjects (such as technology, mathematics, etc.) is identified. Löfving (2023) [14] emphasizes the importance of supporting teachers in the process of students' acquisition of cross-curricular digital competence.

The application of cross-curricular connections in computer science and information technology education is explored from different perspectives:

- Usage of software tools:

Researches are carried out, aimed at using various software tools to consolidate knowledge and skills in other school subjects. In [15], the implementation of project-based learning by using cross-curricular connections in order to acquire skills in creating teaching aids is described. Approaches to developing and upgrading mathematical skills using Microsoft Excel are explored [16], [17]. Bazurin et al. (2022) [18] propose a practice-oriented approach, implemented using a system of practice-oriented tasks with mathematical content.

- Assisting with programming education:

The purpose of other research is to support programming education. Todorova et al. (2021) [19] represent tasks implemented using Scratch and Python that assist the processes of perception, understanding, and application of some basic algorithms when learning elements of programming in 5th and 6th grades. Consideration of the possibilities for cross-curricular connections in programming education is performed in a number of contemporary studies. In [20], a systematic review of the scientific literature in recent years (between 2006 and 2021) regarding the integration of computational thinking in mathematics education in school education is conducted.

The study by Merino-Armero et al. (2022) [21] analyses and demonstrates the effectiveness of an unplugged cross-curricular introduction of computational thinking in the field of social studies among sixth grade students in a Spanish school. For this purpose, students are tasked with programming an imaginary robot on paper in the field of social sciences.

Mannilla et al. (2023) [10] represent a cross-curricular teaching style conducted in four Finnish schools. The results of the cooperation of students from grades 4-6 who work together on a project combining arts, design, and computer technology, programming with other subjects in order to promote computational thinking are analyzed.

The present study is aimed at making cross-curricular connections through Python programming in the teaching of computer modeling in the 6th grade of the Bulgarian education system.

3. Possibilities for Cross-Curricular Connections Through Python Programming in Computer Modeling Education

Among the main advantages of studying computer modeling for students are the development of algorithmic thinking; stimulation of creativity; consolidating knowledge; and skills from other subjects such as solving mathematical problems or creating a project requiring the realization of cross-curricular connections.

In this section, example projects are represented, implementing cross-curricular connections with the subjects of mathematics, history, geography, human, and nature, which are summarized in Table 1.

Table 1. Tasks implementing cross-curricular connections with other subjects

Subject	Task	Computer modeling concepts and skills	Concepts and skills from the other subject
Mathematics	Finding the number of digits in an integer entered from the keyboard or received as a randomly generated value	Integer variable, converting a number to a string, finding the length of a string, conditional operator, library for random numbers	Integer
	Finding the sum of the digits of a natural number	Finding the whole part and remainder when dividing by 10, looping algorithm	Representation of a natural number as a sum of hundreds, tens, and units
	Finding the prime divisors between 1 and 20 of a given integer	Finding remainder in division, conditional operator, looping algorithm, list operations	Divisor, prime number, remainder on division
	Drawing a rectangular coordinate system; visualization of points with given coordinates; connecting them in a figure	Importing the turtle library, drawing lines, filling with colour	Rectangular coordinate system, coordinates of a point, determination of a point by its coordinates
	Drawing the direct proportionality graph	Importing the turtle library, drawing lines, creating a function	Direct proportionality, coefficient of proportionality, direct proportionality graph
	Calculating the circle length and the circle area; drawing a circle, fill a circle with colour	Importing the turtle library, drawing circle, filling with colour, calculating a value by formula, creating a function	Circle length and circle area, radius, formulas for calculating the circle length and the circle area
	Calculating perimeter and area of a regular polygon; drawing a regular polygon; filling a regular polygon with colour	Importing the turtle library, drawing lines, filling with colour, calculating a value by a formula, creating a function	Perimeter and area of a regular polygon, apothem, formulas for calculating perimeter and area of a regular polygon
History	Create a timeline with points corresponding to events	Importing the turtle library, adding a character, setting a character state	Time in history, chronology, concepts related to the specific events
Geography	Setting background map; changing the turtle shape to an airplane; traveling a certain distance at a given scale in a certain direction	Importing the turtle library, setting background, character state, list operations, looping algorithm	Directions, scale, map orientation, scale distance calculation
	Setting background map; drawing circles with centers denoting the locations of given cities and radii that illustrate a numerical feature (such as population)	Importing the turtle library, setting background, character state, list operations, looping algorithm	Theme map, map with proportional point symbols
Human and nature	Creating a function for calculating the distance travelled for a given time and speed; conversion of the measuring units for time and speed	Inputting data from keyboard, converting string to numeric type, conditional operator, creating a function	Distance, time, speed, unit of measurement for distance, time, speed, calculation of distance covered by given time and speed, conversion of measurement units for time and speed

Results of the implementation of some of the tasks are shown in Figures 1-5.

- *Mathematics*:

Task. A rectangular coordinate system has to be drawn, the points with the corresponding coordinates A(-3; -3), B(3; -3), C(3; 2), D(0;4), E(-3; 1) have to be visualized and connected in Figure ABCDE (Fig. 1).

If the area of the resulting Figure ABCDE has to be found, filling in the excess by colouring the triangles suggests that the sum of the areas of the coloured triangles must be subtracted from the area of the rectangle.
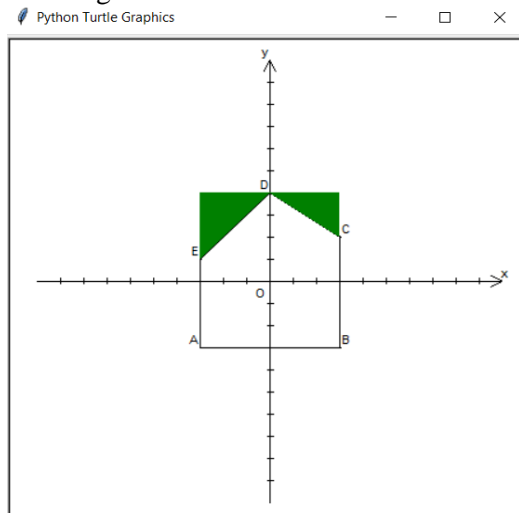

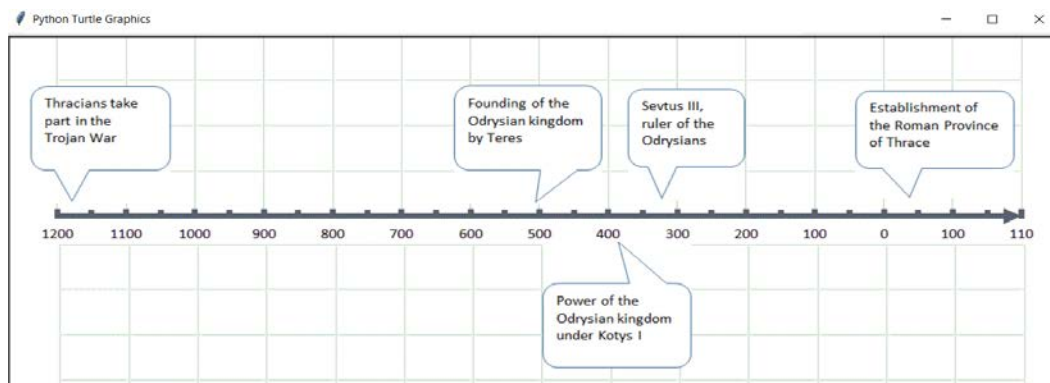*Figure 1. Coordinate system and points with given coordinates*

- *History*:

Task. A timeline has to be drawn and the events from a pre-defined list in the correct place have to be positioned. For the purpose, different characters have to be created, that change their state using an image from an external file.

Figure 2 shows a timeline on which the following facts are plotted:

- The beginning of the 12th century BC – Thracians take part in the Trojan War;
- The end of the 6th – the beginning of the 5th century BC – foundation of the Odrysian kingdom by Teres;
- 383 – 360 BC – power of the Odris kingdom under Kotis I;
- 330 – 300 BC – Sevtus III, ruler of the Odrisians;
- 45 – establishment of the Roman province of Thrace.

Figure 2. Timeline with events depicted

- *Geography*:

Task. The background map of Europe has to be set and the shape of the turtle to be changed to an airplane which has to be located in Veliko Tarnovo. The plane must travel in a certain direction a concrete distance at a given scale, for example traveling from Veliko Tarnovo to Prague – a distance of 1154 km, 315 degrees north-west.

The scale in the implemented example is 1:300000, i.e. one turtle step on the map corresponds to 300 000 cm of actual distance, therefore 3 km (Fig. 3).

By this way, an application of proportions to calculate distance using a map scale is demonstrated.

In the simpler version of the task, it can be implemented for one destination. With more destinations, it is possible to store their data in a list of the type:

```
list = [
    [ name_1, distance_1,
      direction_1, degree_1 ], …,
    [ name_n, distance_n,
      direction_n, degree_n ]
]
```
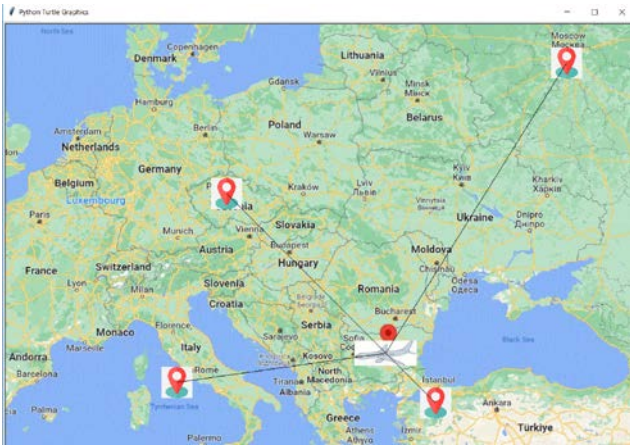
Figure 3. Distances travelled at a given scale in a given direction

Task. The locations and population numbers of several towns are given. A map of Bulgaria has to be set as a background and circles with the cities as centres to be drawn. The circles' radiuses should be calculated as a percentage of the total population numbers in the cities under consideration. The circles represent the population number in the respective city (Fig. 4).
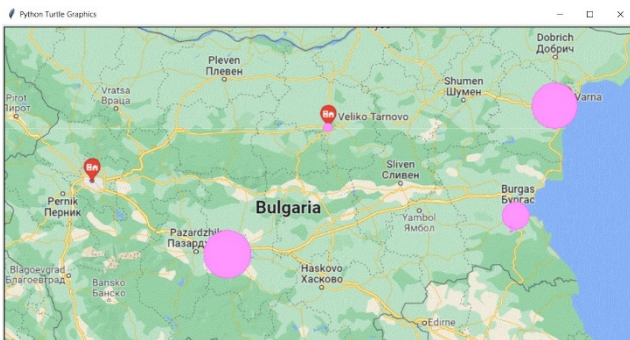

Figure 4. Illustrating the number of population in given cities (Veliko Tarnovo, Varna, Burgas, Plovdiv)

Thus, the radius of each circle can illustrate a numerical feature such as a population count for the particular task. Another option is the settlement of a different fill shade for circles that have the same or different radius sizes.

A possible way of implementing the task is to ensure the storage of data on cities, their population, and coordinates in a list of the type:

```
list = [
    [name_1, population_1,
    [x_1, y_1]], …,
    [name_n, population_2,
    [x_n, y_n]]
]
```



```
1  # Time and speed input
2  t = float(input("Enter the time:"))
3  while t <= 0:
4      t = float(input("Enter the time:"))
5  tm = input("Enter the time measurement unit (s, min, h):")
6  v = float(input("Enter the speed:"))
7  while v <= 0:
8      v = float(input("Enter the speed:"))
9  vm = input("Enter the speed measurement unit (m/s, km/h):")
10 # Distance calculation function
11 def compute_s(t, v):
12     if tm == "s":
13         t = t/3600
14     elif tm == "min":
15         t = t/60
16
17     if vm == "m/s":
18         v = v * 3.6
19     s = t * v
20     return s
21 print("The distance covered is (в km/h): ", compute_s(t, v))
```

```
Running: 11 hn example4 enq.py
Enter the time:10
Enter the time measurement unit (s, min, h):min
Enter the speed:10
Enter the speed measurement unit (m/s, km/h):m/s
The distance covered is (в km/h):  6.0
```

Figure 5. Calculation of the distance covered at a given time and speed

- *Human and nature*:

Task. A function has to be created which calculate the distance travelled for a given time and speed. The possibility for conversion of measurement units for time and speed has to be ensured (Fig. 5).

4. Conclusion

In the present paper, existing research on making cross-curricular connections through the use of information technology and programming in different languages in the education of the field of computer science are examined. Sample Python projects suitable for 6th grade students are proposed and the concepts and skills that reinforce and condition the implementation of the cross-curricular connection are summarized. The developed projects are available in different variants of different complexity. They are published in a git repository https://github.com/tsvetankageorgieva/computer_modeling, which allows their future reuse for learning purposes.

Future work includes implementing the proposed tasks in JavaScript; supplementing the collection of sample tasks with new solutions to the proposed ones, as well as formulating new project requirements and their implementations for the 6th grade, adding tasks suitable for the 7th grade.

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