Teaching the angle as direction using visual programming

KONSTANTINOS KAKAVAS, KONSTANTINOS ZACHAROS, IRINI SKOPELITI, VASSILIS KOMIS

*Department of Educational Sciences
and Early Childhood Education
University of Patras
Greece
kkakavas@upatras.gr
zacharos@upatras.gr
eskopel@upatras.gr
komis@upatras.gr*

ABSTRACT

The present research is part of a wider study, which aims to teach the concept of angle using the visual programming language Scratch. Four semi-structured real-world digital simulations were designed that highlighted the angle as a "change of direction" of an object's initial position or initial trajectory. The research involved 35 sixth grade students who used Scratch to design the digital simulations in order for the students to master the aspect of the concept of the angle related to "direction". It was found that visual programming can be used satisfactorily to teach "direction" as a sub-dimension of angle. Specifically, 32 students designed at least 3 correct digital simulations, while a variety of strategies were observed that students used to achieve the goal of each task. It was also found that Scratch helped the students effectively manipulate the dynamic characteristics of the angle in each situation they designed.

KEYWORDS

Concept of the angle, angle as direction, Scratch, visual programming

RÉSUMÉ

La présente recherche fait partie d'une étude plus large qui vise à enseigner le concept d'angle en utilisant le langage de programmation visuelle Scratch. Quatre simulations digitales semi-structurées du monde réel ont été conçues pour mettre en évidence l'angle comme un "changement de direction" de la position initiale ou du chemin initiale d'un objet. La recherche a impliqué 35 élèves de sixième année qui ont utilisé Scratch pour concevoir les simulations digitales afin que les élèves maîtrisent l'aspect du concept d'angle lié à "la direction". Il a été constaté que la programmation visuelle peut être utilisée de manière satisfaisante pour enseigner la "direction" en tant que sous-dimension de l'angle. En particulier, 32 étudiants ont conçu au moins trois simulations digitales correctes, tandis qu'une variété de stratégies ont été observées que les étudiants ont utilisées pour atteindre l'objectif de chaque activité. Il a également été constaté que Scratch aidait les étudiants à manipuler efficacement les caractéristiques dynamiques de l'angle dans chaque situation qu'ils concevaient.

MOTS-CLÉS

Concept d'angle, angle comme direction, Scratch, programmation visuelle

INTRODUCTION

The concept of angle is a quite complex and multidimensional concept (Henderson & Taimina, 2005; Mitchelmore & White, 2000), a fact that is also evident in the difficulty of having a single definition of it. Some researchers emphasize the distinction between the static and dynamic characteristics of the angle (Freudenthal, 1973; Kieran, 1986; Scally, 1986). Devichi & Munier (2013) attribute to the angle the properties of rotation, space and the meeting of straight lines, semi-straight lines, or line segments. Attempting a different formulation of the definition of the angle, Tanguay & Venant (2016) consider as angles the two parts of the plane formed by the meeting of two straight lines, one of which is considered as a convex angle and the other as a non-convex angle.

Our view is that the definition of angle acquires meaning and significance through the specific features that compose a state (situation) of the real or geometric world. In this view, the activities designed by the researchers or teachers set the limits for the dimensions of the angle that are taught each time, but also the exploitation of the dynamic or static character of the angle.

In the present research it was chosen to teach the case of "direction" as one of the seven dimensions of angle (rotation, meeting, slope, object angle, turn, direction, space) presented in the categorization of the concept of angle proposed by Mitchelmore & White (1998). We believe that this categorization provides a detailed distinction of the individual dimensions of angle and at the same time can provide a framework for planning activities related to the concept of angle. The case of "direction" was chosen, as there is little research that investigates this aspect (e.g., Mitchelmore & White, 2000).

Regarding the most appropriate educational techniques, several studies show learning benefits from the use of digital technologies in the teaching of concepts of Geometry (e.g., Balomenou et al., 2017). Particularly, various research highlights the benefits of students from the application of digital technology in teaching the concept of angle (Bartolini Bussi & Baccaglini, 2015; Fahlgren & Brunström, 2014).

Regarding the application of the visual programming language Scratch, research shows that it can be used to enrich the teaching of Geometry with new types of activities (Ke, 2014; Zavala et al., 2013). At the same time, research has shown that the application of Scratch can have significant benefits for students in understanding the concept of angle but also in improving misconceptions about this concept (Kakavas & Zacharos, 2019; Kakavas et al., 2021). Furthermore, it seems that students have a positive attitude towards the use of Scratch (Genç & Karakuş, 2011) and that the use of Scratch may help students to develop their creativity (Kobsiripat, 2015).

The main purpose of this paper is to examine the effect of the application of visual programming, and in particular Scratch, on the understanding of "direction" as one of the aspects of the angle, in the context of designing digital simulations of real-life situations.

RESEARCH QUESTIONS

For the needs of this research, the following research questions are formulated:
1. Can students digitally simulate through Scratch the change of direction in real world situations as a dimension of the angle?
2. Can students relate the size of the angle in the digital environment to the specific characteristics given of the change-of-direction situation from real world?

METHODOLOGY

The present research is a case study (Cohen & Manion, 1994) implemented in real classroom conditions. The research was designed and implemented within the framework of the design-based research model (Wang & Hannafin, 2005). It is a qualitative research and methods of qualitative analysis of the resulting data were used.

Sample

The survey involved 35 sixth grade students, aged approximately 12 years. The students attended two public primary schools in a city in Greece. Convenience sampling was carried out, as the students who participated in the research were selected so that the school, they attended, had the necessary equipment (computers, projectors, internet connection, etc.). All ethical rules were applied and the students voluntarily participated in the research with the consent of their parents.

Material

For the needs of the research, 4 semi-structured digital microworlds were designed by the researchers and the students had to complete them according to the requirements of each task. The digital simulations were related to the cases of the compass, boat, javelin, and football, as described below (Figure 1).

FIGURE 1

Compass

Boat

Javelin

Football
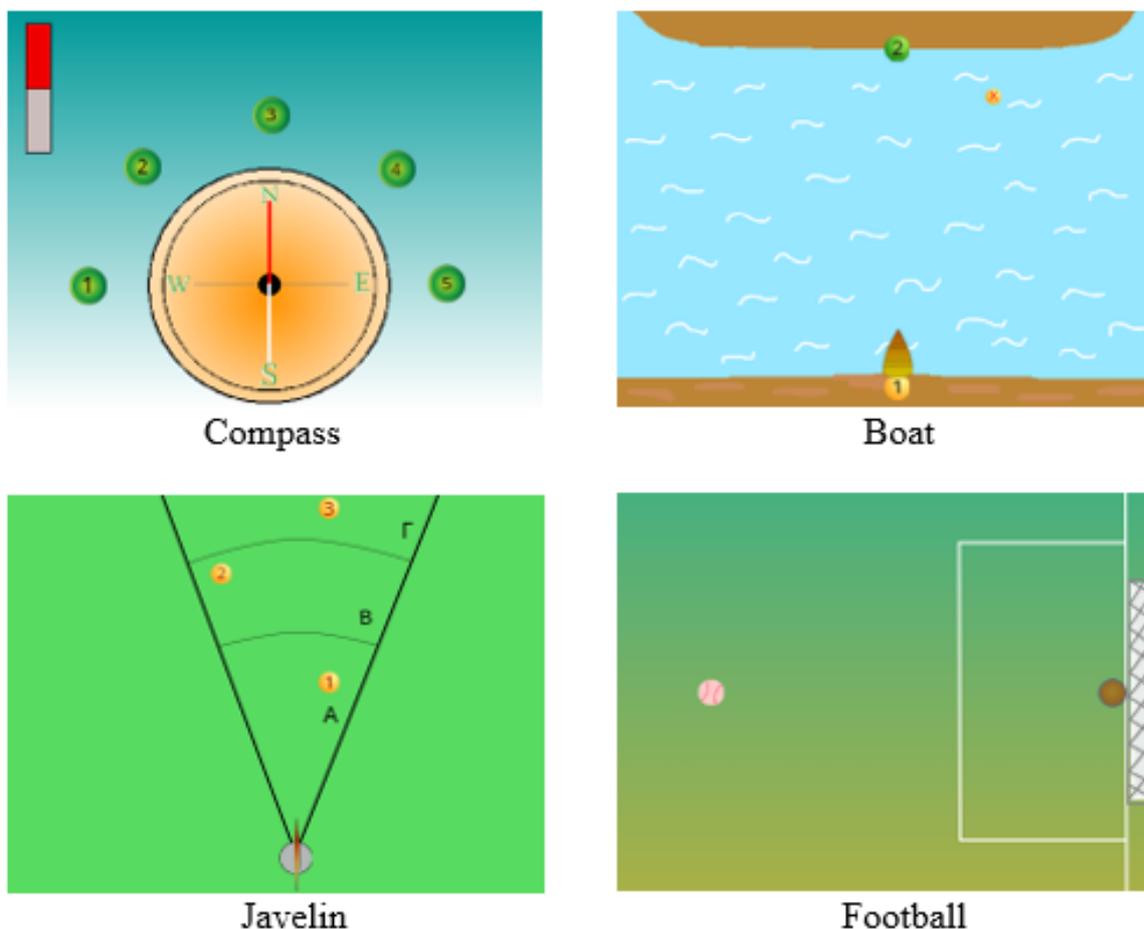
The figures used in the four digital simulations

In the first simulation, students had to show the needle changing direction when a magnet is placed at specific points around the compass. In the second simulation, students had to demonstrate the change of direction from the initial route of a boat due to sea waves. In the third simulation, the students were asked to show the change of direction of a javelin from its initial position when it lands in specific positions in space. In the fourth simulation, students had to demonstrate the change of direction of a soccer ball so that it ends up in a soccer goal net. Also, worksheets were designed with questions related to the understanding of each angle situation. Two examples of such questions are: "Verbally describe the change of direction of the javelin so that it ends up at point 1" and "How much can the direction of the javelin change left and right form the initial position so that it makes a valid shot?".

Process
The research process was carried out in a school computer lab where students worked individually. During the design of each simulation, each student's screen was recorded with the free software Bandicam showing the evolution of the code they developed and the way they worked. In addition to designing the simulations, the students answered the questions on the worksheets.

Analysis of data
The data from each digital simulation were categorized into three categories, which were related to the degree to which the students achieved the goal in each task, taking into consideration the degree to which students' designed simulations represented the real world and the data of each task. The categories are the following:
1) *Correct*: The simulation correctly represents the real change of direction of objects and conforms to the requirements of the task.
2) *Incomplete*: The simulation partially represents the real change of direction of the objects and does not match the requirements of the task.
3) *Incorrect*: The simulation does not represent the actual change of direction of the objects and does not match the requirements of the task.

RESULTS

The research showed that 125 digital simulations out of 140 that the students designed in total were correct (89.3%). Also, 32 students managed to complete at least three simulations correctly, while 24 students completed all four simulations correctly (Table 1).

TABLE 1
Number of correct simulations per student

	1 correct simulation	2 correct simulations	3 correct simulations	4 correct simulations	Total
Number of students	1	2	8	24	35

The students showed a high degree of success in each digital simulation separately. It was observed that for each distinct task there were at least 30 students who managed to create a correct simulation and that students showed a greater degree of success in the case of the boat (32 students) and in the case of the football (33 students) (Table 2).

TABLE 2
Number of students that designed correct simulation

	Compass	Boat	Javelin	Football	Total
Number of students	30	32	30	33	35

To better understand how the students worked and how they evolved their coding in order to design their simulations, we evaluated the recordings from the students' screens. The case of the javelin is presented below as an illustrative example. The students' work in the rest of the simulations was evaluated in a similar way. Table 3 presents the degree of success of the students in designing the change of direction of the javelin during its diversion towards the three different points of the space in relation to its initial position.

TABLE 3
Degree of success at javelin diversion to the three points of space

| Degree of success	Diversion to point 1	Diversion to point 2	Diversion to point 3
Correct	32	32	34
Incomplete	3	3	0
No design	0	0	1
Total	35	35	35

From the table above, it appears that most of the students managed to design a correct simulation where the change of direction of the javelin is presented towards all three predetermined points of the space, within which a throw of the javelin is considered valid. Conversely, there were very few students who designed an incomplete simulation and very few who did not develop at all the semi-structures simulation given to them.

Correct simulation strategies
From the analysis of how the javelin simulation was designed, three strategies that the students applied emerged. For the case of the simulation in which the javelin ends up at point 1 the strategies are presented below. The first strategy is applied by 14 students, the second strategy by 3 students and the third strategy by 15 students.

According to the first strategy (Figure 2), the students initially tried to rotate the javelin around its axis while it remains in its original position. They chose the measure of the angle so that if the javelin moves forward, it could reach point 1. Next, they found the number of steps required for the tip of the javelin to touch point 1. Finally, they combined the "turn" command and the "move" command with their correct numerical values.

FIGURE 2
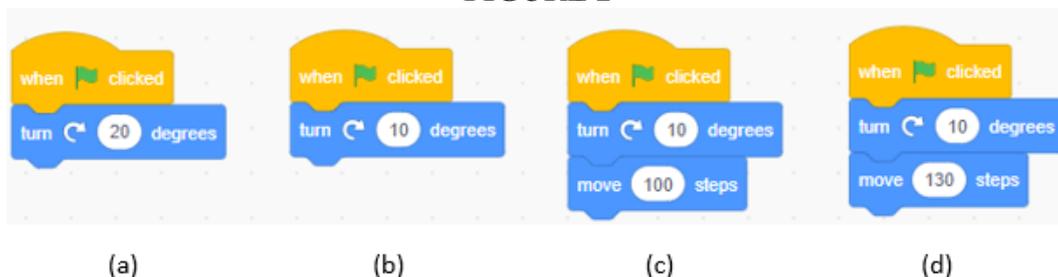
Strategy 1 used by students

According to the second strategy (Figure 3), students followed a planning process which is the reverse of the one followed by the students who used strategy 1. Specifically, they initially tried to find the number of steps required so that the tip of the javelin reaches the same level as point 1. Then, they tried to find the measure of angle at which the javelin would rotate around its axis while it is in its original position, but its imaginary extension passes through the point 1. At the end they combined the command "move" and the command "turn" with their correct numerical values.

FIGURE 3
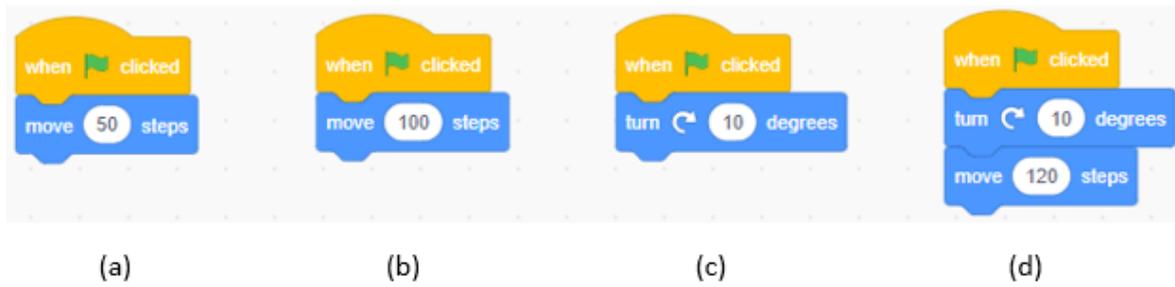
Strategy 2 used by students

According to the third strategy (Figure 4), students combined from the beginning the commands "turn" and "move" at the same time. They understood the important role and relationship of these two commands, looked for the necessary numerical values for each of them and handled them simultaneously. So they observed where the javelin ends up according to the combination of the two commands and changed the numerical values so that the javelin eventually ends up at point 1.

FIGURE 4
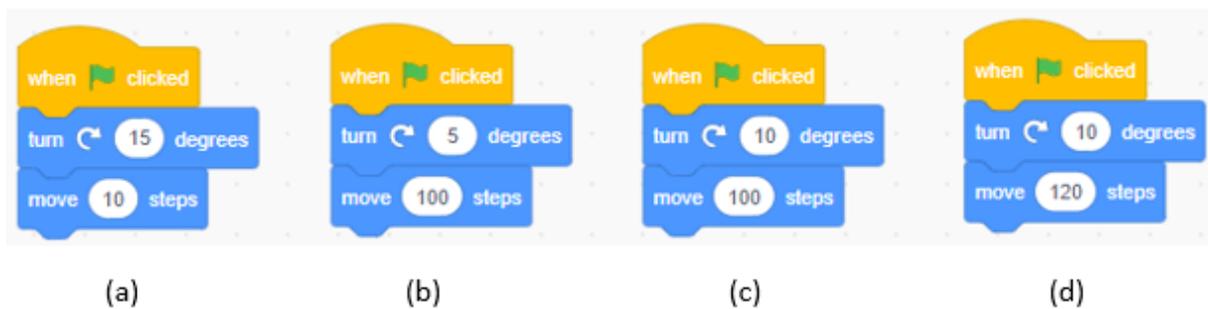
Strategy 3 used by students

Incomplete simulation strategies
There are two strategies used by the students who designed incomplete simulation (Figure 5). The first strategy (Figure 5a), although it contains the correct "turn" and "move" commands, does not correspond to the data and requirements of the activity. In particular, the set of these commands makes the javelin execute a curved trajectory in the plane and not a straight one as defined by the activity. The second strategy (Figure 5b) also belongs to this category as the order of placement of the commands in the body of the code is not correct. In this case, the javelin moves forward and at the point where it stops it rotates around its axis.

FIGURE 5
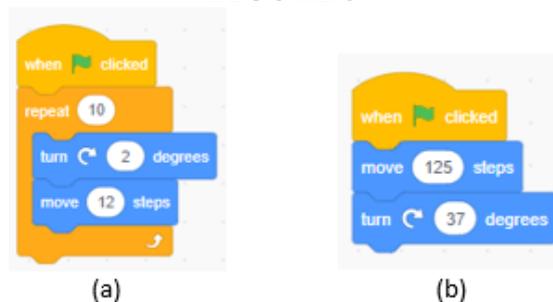
Incomplete simulation strategies

Evaluation of worksheets

In addition to the digital simulations, the worksheets completed by the students were also evaluated. One of the main questions on the javelin worksheet was for the students to find the measure of the total angle within which a shot is considered valid and design that total angle on paper. The researchers designed the total angle to correspond to 40°, i.e., 20° to the right and 20° to the left of the initial position of the javelin. The correctness of the students' answers is presented in Table 4.

TABLE 4
Degree of success at finding the total measure of the angle

| Degree of success	Number of students
Correct	23
Incorrect	9
No answer	3
Total	**35**

From the above table it appears that most of the students (N= 23) managed to correctly calculate the total angle and draw it correctly on the paper. To calculate the measure of the angle they would have to do several tests by changing the direction of the javelin to the right and to the left in relation to its original position. Thus, it was observed that students' continuous interaction with Scratch helped them to continuously receive immediate feedback on their every action. This feature allowed them to tweak the code they developed each time until they were able to find the measure of the required angle. Figure 6 shows indicative incorrect designs. Figure 7 shows indicatively correct drawings of the total angle drawn by the students. It is noted that the value of 42° has also been considered as correct due to a small deviation from the correct value.

FIGURE 6
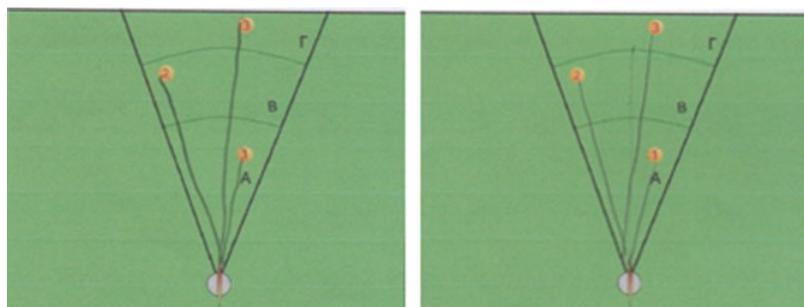
Incorrect drawings

FIGURE 7
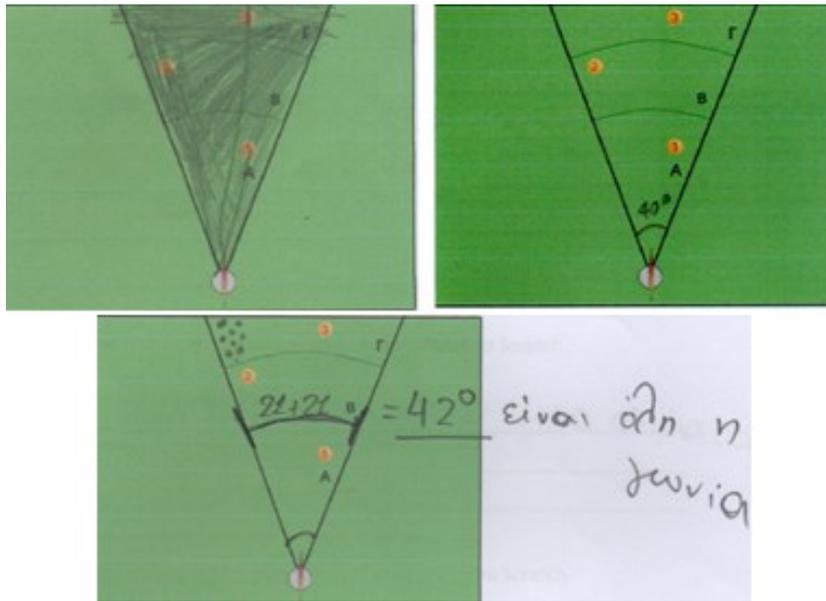
Correct drawings

CONCLUSIONS

The results of applying visual programming, particularly Scratch, to the teaching of direction as an aspect of the angle are quite encouraging. It was found that students can design digital simulations of real-world angle situations, since 125 simulations out of the 140 totally constructed were correct (89.3%). Thus, 32 of the 35 students who participated in the survey designed at least 3 correct digital simulations out of the 4 they designed in total, while 24 students designed all simulations correctly. At the same time, it was observed that students used a variety of strategies to complete each simulation. It appeared that the students evolved the strategies they used to complete each task, as the interaction with Scratch and the continuous feedback they received encouraged them to design improved simulations.

Regarding the understanding of the concept of angle, the research showed that there are four main elements that students seem to take into account when designing simulations: (a) The angle and its measure are the determining factors for the successful completion of the simulations, (b) the angle and its measure are related to the change of direction of the initial position or route of the object, (c) the angle and its measure are related to the change of direction "to the right" and "to the left" and (d) the vertical or horizontal axis was used as reference axis.

At the same time, the results showed that the understanding of the concept of the angle is observed not only at the digital environment but also at the "paper-pencil" environment since most of the students managed to correctly draw the overall angle of the activities. Moreover, it appeared that students understand the concept of angle not autonomously but as part of a wider system of relationships characterizing a real situation. Thus, they link the specific characteristics of each angle situation of the real world to the completion strategy of each simulation. These results strengthen the view about the concept of the angle, according to which the definition of an angle acquires meaning through the specific features that make up a situation in the real or the geometric world.

DISCUSSION

The findings of the present research show that the visual programming language Scratch can help students understand various dimensions of the angle concept and improve their understanding about the concept. Moreover, it seems that Scratch is a friendly environment that can support the teaching of the concept of angle and that can expand this beyond the boundaries of the geometric world. The active participation of students and the immediate feedback they receive from Scratch are the key elements that support the teaching and understanding of the dynamic features of the angle concept. Related findings are presented in the research of Kakavas (2023) in which Scratch is used to teach different dimensions of angle and to support students' understanding of them. Similar are the research findings that show that students have a positive attitude towards Scratch (Genç & Karakuş, 2011), that it has a positive effect on students' creativity (Kobsiripat, 2015) and that Scratch can be used to enrich the teaching of Geometry with new types of activities (Ke, 2014; Zavala et al., 2013).

However, the research is a case study involving a small sample of students. Future research may include a larger number of participants and study the effect of other technological tools on angle understanding.

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