Determining the Effect of Programming Language in Educational Robotic Activities

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Abstract— **Robotics has been suggested as a field of high potential in education and with high expectancy to impact teaching from kindergarten to university. This paper presents a study conducted with the purpose to have a better understanding of the impact of programming languages among participants of a workshop. An activity, which encompasses ten exercises, was designed and we used three different programming languages (i.e. visual, blocky and text) to program the Thymio robot. A total of six workshops were held using this activity two for each programming language. Qualitative and quantitative data were collected in each workshop. The results suggest that despite the programming language used, participants enjoyed working with robots. Moreover participants with previous experience on programming prefer more advance programming languages.**

I. Introduction

Robotics has been suggested as a field with potential in education [1] and with high expectancy to impact teaching from kindergarten to university [2]. Nevertheless, its real impact has not been formally determined [3] neither a guideline were established for designers of workshops and lessons to guide them to combine different factors crucial for the sucess of the activity. These factors are participants previous knowledge, robotic platform, pedagogical methodology, programming language, among others. The correct combination of them is of vital importance to design and implement workshops and lessons that engage participants in them. If these factors are not correctly aligned, the final activity could be counterproductive [4].

However the alignment of these factors could be a difficult task due to the diversity of fields that converge in robotics. This can be noted considering the diversity of skills reported in the literature to be fostered during the activities with robots, which goes from soft skills (e.g. Problem solving [5]) to technical skills (e.g. physics [6] and programming [7]). Nevertheless, few studies have studied the real impact of robotics in education [6] and how to correctly combine diverse factors [8]. In order to understand how these factors should be combined to achieve the desired results, it is required to study them in a real settings. This paper presents a study conducted with the purpose to have a better understanding of the impact of programming languages among participants of a workshop. An activity was designed to be used with the three programming languages available for Thymio II, which are visual programming, blockly programming, and text programming [9]. This activity was used in six workshops offered as part of the ER4STEM project. A total of six groups, three fourth grade and three fifth grade students, came to the campus of the university. Quantitative and qualitative data were collected for each workshops using the material developed for the ER4STEM project and reported in the deliverable 6.1 [10]. The results suggest that independently the programming language used, participants enjoyed working with robots. Moreover participants with previous experience in programming prefer more advance programming languages.

This paper is organized as follows. Section II presents relevant work done on the study of the impact of robotics in education. Section III introduces the platform used in the workshops and the three programming languages. Then, Section IV explains the activity done in the workshops and section V describe how the workshops were held. Finally, Section VI inform the results obtained during the workshop and Section VII presents conclusions and further work.

II. Related Work

Robots has been used to teach different topics. It has been reported that robots were used to teach simple harmonic motion [11], Doppler effect [12], computational thinking [13], teamwork [5], problem solving [5], and programming [14]. In spite of an increasing number of work, measuring the real impact of robotics in education is still needed [3], which help to come with best practices for their use. Nevertheless, the few works reports the impact of robotics uses a self-reported and observation data to quantify the impact of robotics in education [6].

Some reasearchers have used mixed methods to measure participants improvment before, during and after their intervention. This is the case of Douglas and et al. [6] who designed and implemented a physics summer camp. A total of 21 children participated in this camp. They used an evaluation test to verify participants' knowledge before and after the camp. Although their results suggests that the camp increased participants' knowledge in physics, they also found that participants were more motivated to work on assignments that involved the use of robots.

Others, as Ucgul and Cagiltay [8] have studied design issues for training camps using robotics. They carried out two camps, in which a total of 52 children participated. They combined quantitative and qualitative data collection mechanisms, which included interviews, field notes and evaluation forms. Their results show that exercises must be

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Fig. 1. Educational platform Thymio II.

designed from simple to complex. Also they mentioned that the kids suggested small working groups during the activities because this increases the time that they can manipulate the robot.

In a longer study, Sullivan and Bers [14] studied the impact of an 8-week robotics curriculum, which involved the use of tangible language. A total of 60 children from pre-kindergarten through second grade participated. They collected quantitative data in form of two assessments. One assessment was done before the real intervention of 8-weeks took place to assess participants' knowledge in robotics. The second was done after the intervention to control children improvement. Their results show that pre-kindergarten children were able to learn basic robotics and programming, while older children were able to learn more complex concepts using the same kit.

III. Thymio and Programming Languages

Thimio II (Figure 1) is a robotic platform created by the EPFL and it is the second iteration of their attempt to create a low cost platform [15]. It was selected because it has several sensors and actuators that could be used in the workshop. Moreover, it could be programmed using Aseba studio, which provides three different languages paradigms:

- *Visual programming* was designed to let users drag and drop components into a canvas in Aseba studio. Figure 2-a shows the programming interface. As it could be observed, the user can select from events (right) and combine with actions (left).
- *Blockly programming* is the Scracth [16] version for Thymio II. As it could be seen in the Figure 2-b, it provides several components, such as conditionals or variables.
- *Text programming* is a programming language created for Thymio II. Figure 2-c presents an example of a program that reacts when an object is approaching.

IV. The Activity

In order to study the impact of programming languages on participants in a workshop, it was decided to create a structure of an activity that would be used as a base for each programming language. This activity assumes that participants do not have any previous knowledge in robotics and programming. Therefore, it was designed to be an introductory activity on programming robots. The activity is divided in an introductory exercise and ten different exercises. The introductory exercise is a group activity used to welcome the participants and make them reflect about robotics. Ten exercises are designed from simple to complex, as it was suggested by Ucgul and Cagiltay [8]. The introductory and the ten exercises are described below.

A. Introductory Activity: How Robots Perceive

The introductory exercise is used to introduce the participants to the control cycle in robotics. Participants are asked to create groups of four to six people. Each group must select one person that will become the "robot". The selected people are asked to go out of the room with one of the tutors. Meanwhile, the rest of the group must agree on a maze for the "robots". Once they finish the maze, each robot comes inside the room blindfold. When they are inside, his or her group gives instructions on how go through the maze without touching anything. These instructions could be just given once. Once all robots have done the exercise, participants are asked to create groups of two to three people to start working with the robot.

B. Exercise One:Measurements with Thimio

In this first exercise, participants are first asked to test distance sensors and check what happens when objects come closer or farther from them. Then, they are asked to register diverse values for each distance sensors available in the robot. Once they finish with the distance sensors, they are asked to register the values obtained from the microphone while they are chatting in front of the robot, clapping, knocking on the table, and generating noise with the motors. At the end, they are asked to think about the following questions: what is the main differences between robots' sensors and our senses? What do the robots' sensors and our senses have in common? Do you know sensors other than those that Thimio has? Try to name other machines that use sensors.

C. Exercise Two: My First Program

In this exercise, participants create their first program in the programming language assigned for the workshop. The first part focuses on making the robot changes its colors in the following sequence: red, green, blue, yellow and red. Then, they are asked to explore different commands to make the robot move forward and then turn left or right twice.

D. Exercise Three: Listen to Commands!

This exercise is an introduction on how to make the robot react to commands. To achieve this, a piece of code is given that participants must analyze and understand what the code executes. Then they are asked to program the robot to move in the direction of the button that was pressed. By pressing the middle button, the robot should stop.

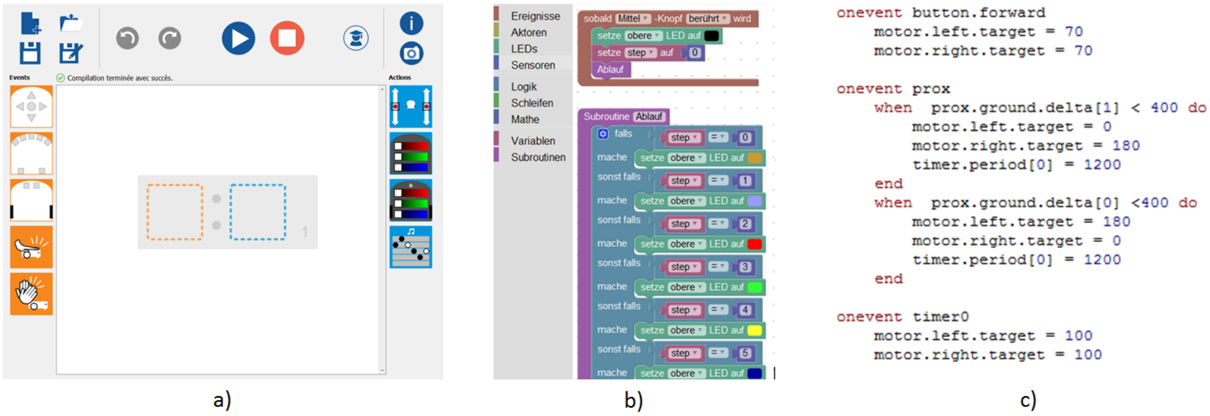

Fig. 2. Programming languages available in Aseba Studio. a) Visual programming. b) Blockly programming. c) Text programming.

E. Exercise Four: Don't fall of the Table!

This exercise introduces participants to Thymio's ground sensors. They are asked to write a program that stops the robot when it detects a table edge or black surface using the ground sensors. To avoid damages to the robot, the participants are provided with a cardboard with a printed maze, which they can use to test their solution.

F. Exercise Five: Finishing Straight

The goal of this exercise is make the participants familiar with the use of Thymio's timer. Therefore, they are asked to program the robot to move for a determined time after the middle button is pressed. Examples showing how to use the timer are provided to them. In this exercise, they can use a printed straight corridor to test their solution.

G. Exercise Six: Avoid a Crash!

This exercise introduces participants how to use distance sensors to make the robot move autonomously without the intervention of the participants. Participants are asked to program the robot to detect objects in from of it. If it detects any object, the robot should turn and then move forward. In this exercise they use the function "when".

H. Exercise Seven: Trip in a Corridor

In this exercise the participants use a curvy printed corridor. The goal is to make Thymio drive through the corridor without crossing the limits. When they have achieved this, they are asked to reduce the zig-zag movement between the two lines, which could be achieved using the timer.

I. Exercise Eight: Friendly Pet

In this exercise Thymio is programmed to become a pet. So, the participants have to program the robot to follow any object in front of it but without being too close. Therefore, they are provided with some examples on how to use conditional statements to achieve the goal.

TABLE I
INFORMATION ABOUT THE TRACK OF THE CLASS AND THE PROGRAMMING LANGUAGE ASSIGNED.

Class ID	Track	Programming Language
Fourth-1	Mixed	Visual
Fourth-2	Science	Blockly
Fourth-3	Language	Text
Fifth-1	Language	Text
Fifth-2	Science	Blockly
Fifth-3	Language	Visual

J. Exercise Nine: Bright Colors

In this exercise the participants are taught how to use different states in programming. They have to program the robot to change color every time that the middle button is pressed. So, the concept of variables is introduced.

K. Exercise Ten: Follow the Line

In this exercise the participants should program the robot to recognize and follow a line on the ground. Participants can use the straight corridor to test their solution.

V. The Study

Three classes corresponded to fourth and three to fifth grade, in the educational system of Austria, participated in the workshops offered at the campus of the university. The six classes came from the same school, which has the particularity that each class follows either a scientific or language track. This means that the classes on the scientific track have more mathematics and technological lessons, while the language track focus on languages lessons, reducing other courses such as mathematics. The assignment of programming language to in each workshops was randomly done. The programming language and track information is provided in Table I. The class id is used to identify the grade of the class through the rest of the paper.

The evaluation kit developed in ER4STEM was used to collect the data.The kit comprises [10]:

- *Handling protocol*, which describes precisely how to use the evaluation material.

- *Pre and post activity questionnaires* that collects personal information, past experience and existing attitudes towards STEM. This helps to evaluate the impact of the workshop on the participants.
- *Draw-a-scientist* provides an understanding on previous stereotypes of the participants towards scientist.
- *Observations of tutors* are comments provided by the tutors that they consider of relevance and that occurred during the workshop. These comments help to inform the late analysis of the data.
- *Interview questions and protocol* defines the way the data is collected, stored and shared.
- *Students reflections and artifacts of their learning* are collected and used also to verify the impact of the workshop.
- *Tutor reflection* is a set of questions that are answered by the tutors after each workshop.
- *Inform consent documents*, which provides relevant information to parents and participants about the research done during the workshops.
- *Reporting templates* establish the basic structure on how the information is reported.

A. Procedure

The preparation of the workshop stars one month before the actual workshop takes place. Participants are provided in advance with the consent forms and draw-a-scientist that they must bring at the day of the workshop. In the day of the workshop, two tutors receive the participants at the entrance of the engineering building and accompany them to the computer room, where the workshop takes place. These tutors are master students hired to implement the workshops. They do not have previous experience in teaching and their presence during the workshop is to support the participants when any problem is raised. When the participants arrive to the computer room, the tutors give to them a code number to each one to anonymize their identity. After, it is done the pre-questionnaire, in which participants introduce their code number. Once all participants have finished the pre-questionnaire, the tutors start with the introductory exercise. Once the exercise is completed, each group is assigned to a computer, provided with a Thymio and a description of the first exercise. While they are starting with the first exercise, the tutors ask within the groups that have agreed on their consent forms to be recorded to be the focus group. Once the focus group has been designated, the tutors provide them a GoPro camera, which they can use to register what they considered as relevant. Every time each group finishes one exercise the next one is provided to them. During the whole workshop the two tutors are present to answer any questions or help the participants in case of difficulties. 30 minutes before the end of the workshop, the focus group is interviewed, which takes around 10 minutes. When they come back, it is started with the post-questionnaire.

TABLE II
STATISTICAL INFORMATION OF EACH CLASS.

Class ID	**Gender**		**Age**	
	Male	**Female**	**Average**	σ
Fourth-1	6	14	13.9	0.9
Fourth-2	12	6	13.8	0.38
Fourth-3	3	18	13.76	0.54
Fifth-1	8	11	14.9	0.71
Fifth-2	10	12	15	0.81
Fifth-3	7	17	15.1	0.63
Total	**46**	**78**	-	-

VI. RESULTS

A total of 124 participants participated in the six workshops: 46 males and 78 females. The average age was 14.4 with a standard deviation of 0.89, minimum age was 13 and maximum 18. Table II presents the information divided by class.

A. Qualitative Data

From the interviews done to the focus groups, it was observed that they agreed that during the workshop they programmed a robot. Some groups also stated that they had fun during the workshop (i.e. Fourth-1, Fifth-1 and Fifth-2). For some groups (e.g. Fourth-1), the workshop was their first experience with robots. Nevertheless, they found the activity very appealing and easier than they expected (i.e. Fourth-1). Participants with previous experience in programming found that working with robots was different that just programming (i.e. Fifth-1). And participants with previous experience in robotics admitted that they learnt something new (i.e. Fourth-2 and Fifth-2). When they were asked about the challenges found during the workshops, some groups mentioned explicit numbers of exercises. For example, exercise 2 was mentioned by Fifth-2, 6 by Fourth-1 and 7 by Fourth-2.

One interesting aspect reported by the tutors took place with class Fifth-2, which follows a scientific track. They reported that for first time the participants showed really interest in the workshop, after having conduct three workshops. Nevertheless, one students told one tutor that she would prefer using a real programming language in the workshop instead of using Blocky. In the next workshop, with class Fourth-3, the tutors reported that participants looked more interested than classes that were exposed to other programming languages.

This information strength the positive impact of robotics in education and at the same time stars to revel some preferences of the participants towards the programming languages. For example, participants with previous experience in programming would prefer textual programming, such as it was reported by the tutor. Regarding participant without previous experience, there is not any relevant information that could lead us to the impact of programming languages in the workshops.

B. Quantitative Data

Figure 3 shows the stars given by participants to their workshop. As it could be observed, class Fifth-2 has given

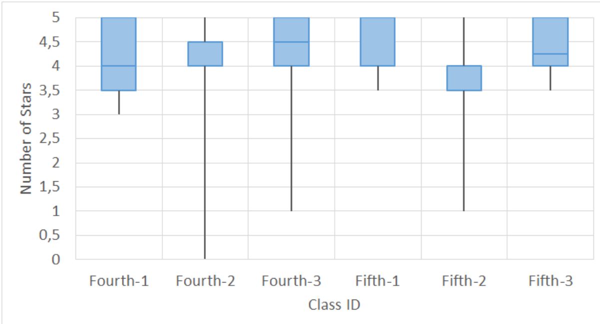

Fig. 3. Box plot of the number of stars given by the participants to their workshop.

a lower rating to the workshop in comparison to the other classes.

To determine if there is enough evidence to conclude that programming languages, independent variable, had an impact on the perception of the workshop, it was done a Fisher's exact tests on nine combinations of the classes. Fisher's exacts test was used instead of chi-squared because the contingency tables contained more than 20% of the cells with values lower than 5 [17]. Additionally, a Benjamini and Hochberg correction was applied for multiple comparisons to get a better p-value estimation. The following are the hypothesis used:

- H_0 = there is not a difference between the programming language used in the workshop and the participants' rating of the workshop.
- H_1 = there is a difference between the programming language used in the workshop and the participants' rating of the workshop.

The results are reported in Table III. As it could be observed, it is possible to accept H_1 for the following pairs: Fourth-1 vs Fourth-2, Fourth-2 vs Fourth-3, Fifth-1 vs Fifth-2, Fifth-2 vs Fifth-3 and Fourth-2 vs Fifth-2. These results are interesting because they suggest that there is no differences between the groups that follow same track and were exposed to a different programming language. Also they show that there is a difference between the groups that follow science and language track. They also show that there is a difference between the two groups that follow the science track and were exposed to the same language. These results and observations recorded suggests that science track participants did not perceived the workshop interesting. Same test was used to verify if there was any difference in the answers between males and females. The group Fifth-1 was the only group in which the answers were different between males and females ($p = 0.032$).

It was also done an analysis on the number exercises resolved by each class, which brings information about the performance of the groups. Figure 4 shows the number of exercises solved by each class. As it could be observed, the class that solved less exercises was Fourth-3, which corresponds to the class following language track and using textual programming. Interestingly the two scientific classes,

TABLE III

Pair comparison among nine different combinations using Fisher's exact test with $\alpha = 0.05$ for the number of stars given and the number of exercises resolved by each class in their respective workshops. The * indicates that the p-value was adjusted using the Benjamini and Hochberg correction for multiple comparisons.

Pair Compared	Number of Stars		Number of Exercises	
	p-value	p-value*	p-value	p-value*
Fourth-1 vs Fourth-2	0.015	0.034	0.58	0.65
Fourth-1 vs Fourth-3	0.28	0.36	0.0095	0.085
Fourth-2 vs Fourth-3	0.008	0.026	0.059	0.23
Fifth-1 vs Fifth-2	0.0013	0.012	0.092	0.23
Fifth-1 vs Fifth-3	0.68	0.77	0.45	0.58
Fifth-2 vs Fifth-3	0.0088	0.026	0.32	0.58
Fourth-1 vs Fifth-3 (Visual)	0.108	0.16	0.1	0.23
Fourth-2 vs Fifth-2 (Blocky)	0.025	0.045	0.68	0.68
Fourth-3 vs Fifth-1 (Textual)	1	1	0.39	0.58

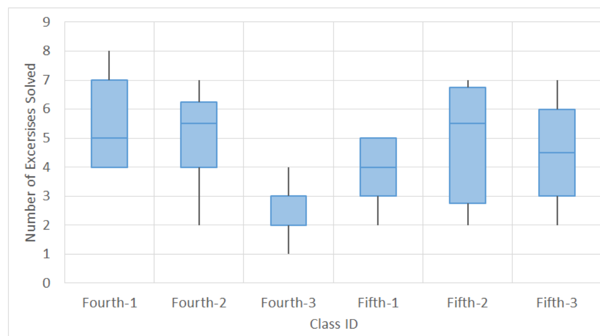

Fig. 4. Box plot of the number of exercises solved in each workshop.

which were assigned to the same programming language (Blocky), have a similar mean but a difference variance in the amount of exercises solved during the workshop, which could suggest that language participants' performance.

The same statistical test was done on this data. The following hypothesis:

- H_0 = there is not a difference between the programming language used in the workshop and the number of exercises solved during the workshop.
- H_1 = there is a association between the programming language used in the workshop and the number of exercises solved during the workshop.

The results are reported in Table III. As it could be observed, there is enough statistical evidence to conclude that there is not a difference between the programming language and the number of exercises solved during the workshop ($p > \alpha$).

Also it was decided to verify if previous experience on robotics or programming could influence the number of start given by the participants. To verify this, it was analyzed the number of participants that have been previously done activities with robotics or programming. Figure 5 presents

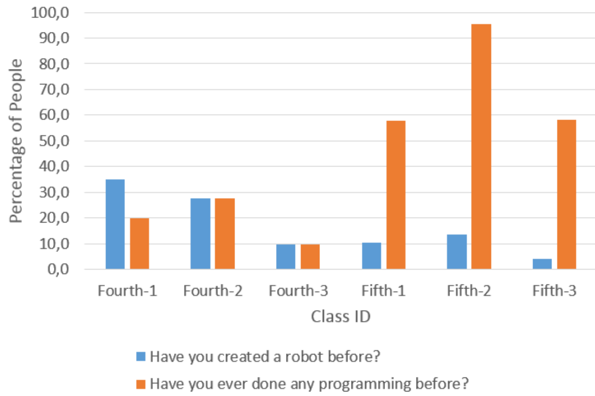

Fig. 5. Percentage of people who have had previous experience in robotics and programming.

the percentage of participants with previous experience on programming and robotics. As it could be observed most of participants (95%) from class Fifth-2 have already programmed, 58% of the participants from classes Fifth-1 and Fifth-3 have also programmed. On the other hand, all the fourth classes have less than 28% of participants with previous experience. This could explain why class Fifth-2 prefer more advance programming languages. This difference on previous experience could explain the differences between Fifth-2 and Forth-2, both following a scientific track and exposed to same programming language. Analyzing in detail this case, it was verified if there is any difference in the number of stars given by those with previous experience in programming and those without. It was done a Fisher's exact test. The result shows that there is not a difference on the stars given by those with previous experience and those who not ($p = 0.083$). A similar result was obtained when it was compared males and females of the two same groups with previous experience on programming ($p = 0.53$).

An interesting aspect is that class Fourth-3 gave a high rating to the workshop even though they were no able to solve as much exercises as the other classes. This raises the question if similar result would have come if the participants would been evaluated after the workshop.

VII. Conclusions and Further Work

This paper has presented an activity to study the effect of programming languages in workshops with robots. A total of six workshops were offered for three groups of fourth and fifth grade. Moreover quantitative and qualitative data was collected for each workshop, which allow to have difference perspectives of each workshop. The results suggest that there is a statistical evidence to conclude that programming languages affect basic programming activities using robotics. In particular to conclude that there was an association between programming language and stars. However personal factors such as previous experience in programming and robotics, age, gender and attitudes towards STEM were not possible to study in the present work due to the limited amount of participants exposed to each programming language. Nevertheless, the results suggest that participants with previous experience in programming prefer more advance programming languages, which is supported by the comments provided by the participants, their rating of the workshop.

Although, the data collected in the work presented in this paper could shows how programming languages have an impact in a workshop, it is still required to determine their real impact and their connection with participants knowledge and preference. Moreover, same works must be done and evaluated in schools because in them additional considerations must be taken in consideration.

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