Article

Mapping K-12 Computer Science Teacher's Interest, Self-Confidence, and Knowledge about the Use of Educational Robotics to Teach

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Abstract: This paper reports a case study, developed in K-12 Portuguese Education, that aimed to analyze the computer science teachers' knowledge, interest, and self-confidence to use educational robotics and other programable objects in classroom activities to teach computer science concepts and to promote students' computational thinking skills. The research design was organized into a descriptive and exploratory quantitative approach. The participants were 174 in-service computer science teachers of Portuguese public education. The data was gathered from the participants, through the online application of the Robotics Interest Questionnaire scale (RIQ). Very positive levels of teacher's knowledge, interest, and self-efficacy to use educational robotics for teaching purposes were reported in the study outcomes. These constructs were underlined in several studies as relevant factors to promote the use of educational robotics and other similar technologies by the teachers. Despite the study limitations and the small context, a set of relevant results was highlighted on computer science in-service teachers' interest and preparation to use robotics and to support their students in learning activities with these artifacts.

1. Introduction

Computational thinking, coding, programming, and robotics have emerged, in the last decade, as thematic trends in scholarly and research contexts.

Authors such as [1] refer the need to consider the existence of computer science teaching in basic and secondary education. With the current digital presence in society, it is important to make citizens capable of dealing with and understanding the digital world. Understanding concepts related to computing, contributes to a better knowledge of how technology works, of information systems, and how to detect and solve problems.

Society expects schools to update their curricula to promote in students the development of essential skills to face the new societal challenges brought about by technology [2]. It is important to stimulate learning with technology, but also learning about technology, which involves computational thinking, programming, and robotics.

Regarding the learning of programming and robotics, there is evidence that it improves the ability to solve problems and overcome obstacles, involving several curricula areas [3]. These are fundamental skills in a highly digital society. If programming allows the materialization in applications of algorithms designed to solve problems or situations, robotics provides the tangible execution of concrete solutions to problems in interaction with the physical world. In contextualized challenges, robotics presents itself with an extraordinary pedagogical potential for approaching multidisciplinary themes and concepts in a practical, tangible, and motivating way [4].

Many countries around the world have revised their school curricula to promote the integration of these themes in the students' curriculum in basic and secondary education. In

addition, several frameworks have been developed, mapping what students should learn about in each school level or grade. The standards developed by the International Society for Technology in Education (ISTE) and by the Computer Science Teachers Association (CSTA) are good examples that inspire the revision of curricula in many countries.

In the Portuguese K-12 curriculum every student should learn about computer science, programming, and computational thinking as well as other digital technologies during each grade of primary and secondary education. There is a subject of information and communication technologies, between the 5th and 9th grade, taught by a computer science teacher.

The curricular framework for that subject defines that each student must develop computational thinking skills through a diversity of pedagogical activities, such as unplugged exercises, block-based programming, and educational robotics problem-solving tasks [5]. Educational robotics is a strong strategy to promote students' skills through problem-solving tasks, and it is an efficient approach to teaching and learning in different learning styles. The pedagogical and didactic potentialities to teach and learn basic programming concepts and computational thinking, even in early education, have been reported in several studies [6–8]. Piedade [5], in a systematic literature review, analyzed 16 papers and underlined the relevance of the use of educational robotics to teach as well as the importance of the teacher's preparation to design and implement robotic learning activities. The importance of using educational robotics in STEAM activities for teaching and learning is evident in several studies, which suggest positive attitudes and interest from students and teachers [9], and positive impact on teacher collaboration, pedagogical approach, and self-efficacy [10].

These changes put in evidence the need to examine the preparation, knowledge, and self-confidence of the computer science in-service teachers to use educational robotics in teaching activities to promote the achievement of curricular goals. According to that, the following research questions were constructed: (i) What are the levels of interest, problem-solving, working collaboratively, and self-confidence and knowledge of in-service computer science teachers to use educational robotics for teaching? (ii) Is there a significant inter-correlation between the constructs? (iii) It is possible to predict the influence of each construct on the others? (iv) Is it possible to identify significant differences in the scores of each construct considering age, gender, and teaching experience?

This study pretends to understand the levels of knowledge and self-confidence of computer science teachers in the integration of educational robotics in a pedagogical context. If it is important to have teachers with adequate preparation and interest in the use of robotics in the classroom, then it is essential to improve teacher training programs regarding the design and development of pedagogical activities with robots.

2. Background

2.1. Computational Thinking

Computational thinking (CT) has received intense attention as an essential skill that all 21st-century citizens should develop. However, computational thinking concerns literature since the early 80s last century. In fact, Seymour Papert's book, *Mindstorms*, referred to 'procedural thinking' while presenting his powerful ideas "(. . .) I have clearly been arguing that procedural thinking is a powerful intellectual tool and even suggested analogizing oneself to a computer as a strategy or doing it" [11] (p. 155).

More recently Wing [12] (p. 32), in a seminal paper, characterized computational thinking as "solving problems, designing systems, and understanding human behavior, by drawing on the contents fundamental to computer science (. . .), using abstraction and decomposition when attacking a large complex task or designing a large complex system". This wide definition for CT clearly relates to mathematical thinking. However, within a mathematical thinking approach to problem-solving, solutions to a problem are generally expressed as integrated formulae, whereas computational-algorithmic solutions typically involve sequences of steps. Step-by-step responses to problem-solving are at the core of

computer algorithms used both to generate solutions as well as serving as heuristics to design processes to solve complex problems.

Wing [13] (p. 3) suggests that CT are "(. . .) thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent". Therefore, we may understand CT as a general problem-solving method that involves several techniques and strategies—such as organizing data logically, breaking down problems into parts, defining abstract concepts and designing and applying algorithms, identifying patterns and models—that could be implemented by digital systems. In his seminal work, Levi-Strauss [14] used the idea of bricolage to contrast the analytic methodology of western science with what he called a 'science of the concrete' in primitive societies. As Turkle and Papert [15] (p. 9) wrote, "the bricoleur scientist does not move abstractly and hierarchically from axiom to theorem to corollary. Bricoleurs construct theories by arranging and rearranging, by negotiating and renegotiating with a set of well-known materials". Computational thinking shares the rationale of not accepting the 'right way' to solve a problem but exploring and seeking new approaches that challenge traditional fixed procedures. Thinking as a bricoleur means to take a mastery of associations and interactions using forms of conceptual navigation that involve adaptation and systematic correction according to one goal.

As recalled by Hoppe and Werneburg [16], to bring computational thinking to K-12, the International Society for Technology in Education and the Computer Science Teacher Association (ISTE and CSTA, 2011) defined CT as "a problem-solving process that includes (but is not limited to) the following characteristics:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them;
- Logically organizing and analyzing data;
- Representing data through abstractions, such as models and simulations;
- Automating solutions through algorithmic thinking (a series of ordered steps);
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources;
- Generalizing and transferring this problem-solving process to a wide variety of problems." (p. 14).

Piedade, Dorotea, Pedro, and Matos [17] refer that after Wing [12,13] many other authors stated definitions of computational thinking as a set of skills related to problem-solving, understanding problems, defining problems, abstraction, logical thinking, debugging and pattern recognition as well as managing information effectively and efficiently with emergent technologies. This represents a shift from an ontological definition for CT towards a skill-based characterization and those authors frame the key dimensions of CT as shown in Table 1.

Table 1. Computational Thinking Skills. (Adapted from Piedade, Dorotea, Pedro and Matos [17]).

CT Skills	CT May Be Definition
Abstraction	Abstraction is the process of taking away or removing characteristics from something to reduce it to a set of essential characteristics.
Decomposition	Decomposition is about breaking problems down into small parts to make them easier to solve.
Generalization	Generalization is transferring a problem-solving process to a wide variety of problems.
Patterns Recognition	Recognizing a pattern or similar characteristics helps break down the problem and also build a construct as a path for the solution. Find a set of patterns or similar characteristics that can be generalized.
Algorithms	The algorithm is the practice of writing a step-by-step sequence of instructions for carrying out a solution or process.
Flow Control	Process of using different flow control structures.
Data Representation	Process of selection of the appropriate models for data representation.

2.2. Educational Robotics

Educational robotics has been signalized in many studies as an instructional strategy to teach fundamentals concepts of programming, to promote the development of computational thinking skills [8,18], to engage students in problem-solving activities [19,20] and to improve students' learning achievements and motivation [21–23]. The findings reported in the studies of Berland and Wilensky [18] and Witherspoon, Higashi, Schunn, Baehr, and Shoop [24] underline an improvement in the students' outcomes.

Additionally, "robotics learning provides an authentic interdisciplinary learning context, such as a STEAM curriculum, for students to learn science, mathematics, technology, engineering, and art design in an integrated and meaningful way" [25] (p. 2). Educational activities based on the use of robotics can help students to assume a more active role in their learning process, to develop many mental skills, and to create new knowledge.

As Vitanza et al. suggest [26] "the usage of multiple robots interacting to solve a common problem can support the learning of concepts related to cooperation and collective actions and can make accessible notions about complex systems that are common in physical, biological, economic and social sciences" (p. 1), such as exploring swarm robotics for educational purposes. Likewise, Chevalier et al. in their study [27] conclude that educational robotics has broad applicability, especially in the development of transversal skills. They found that teachers perceived the utility of educational robotics and that Thymio robot has a high usability at all school levels.

These activities can be drawn from the core principles of Piaget's constructivism, Papert's constructionism, Vygostsky's collaborative learning or Bruner's discovery learning [17]. For example, constructionism principles [11] assumes that the student's knowledge acquiring process is more effective when they are actively involved in building their own knowledge through the construction and interaction with virtual or physical artifacts like robotics. According to this perspective, students learn more efficiently by interacting with tangible objects through authentic, real-world learning tasks and problems that allow a guided and collaborative process where peer feedback is incorporated. According to Tsai, Wang, Wu, and Hsiao [25] (p. 2) "through the real-world hands-on and active problem-solving learning activities, students may find it easier to build, test, and revise a model of the abstract conceptual knowledge learnt in traditional classrooms".

During the learning process of constructing, programming, or interacting with a robot, students apply computational thinking concepts, such as abstraction, decomposition, pattern recognition, logical thinking, and debugging [28–30].

The potential of educational robotics highlights the challenge of its integration in the students' school curriculum. To this end, it is necessary to analyze teachers' perceptions and conceptions about the use of robotics for educational purposes. Thus, it is imperative to provide teachers with training experiences in the use of robotics for teaching, in order to promote their interest and self-efficacy.

Kim, Kim, Yuan, Hill, Doshi, and Thai [31], suggested that robotics can be used as a technology in activities designed to enhance teachers' STEM engagement and teaching through improved attitudes toward STEM. Teachers' knowledge, interest, and self-confidence are critical factor in teaching STEM and in particular computer science.

2.3. Teacher's Self-Efficacy

The self-efficacy concept was proposed by Bandura [32] as the idea of "self-directed mastery", in other words, the ability of people to be self-oriented and actively direct their behavior towards mastery in personal performance. In that perspective the sense of self-efficacy is associated with the sense of proficiency. In the Bandura's perspective, self-efficacy is a self-perception about one's personal abilities to conduct a specific task or to solve a specific problem and uses prior personal experiences in the task performance achievements [32]. Self-efficacy has been shown to be a strong predictor of behavior [33]. However, Bandura [33] (p. 211) refers that self-efficacy is related "with self-perception of competence rather than actual level of competence". Therefore, thinking about the

teaching, the question is not whether teachers can perform a specific task, but rather, what is their personal perception of their ability [34].

Tschannen-Moran, Hoy, and Hoy [35] advocated that the effectiveness of teachers is associated with the ability to successfully design and implement the teaching tasks required in each educational context. In line with that, Schwarzer and Schmitz [36] stated that a teacher with a high sense of self-efficacy presents himself as a proactive teacher, who believes in the existence of the necessary external and internal resources, who takes responsibility for his own professional growth, who focuses on the search for solutions to problems, regardless of the causes of their origin, who choose their paths of action that create meaning and sense for their lives by setting ambitious personal goals. However, teacher sense of self-efficacy is complex and can vary across teaching tasks and contexts [34]. Taking our context of research, a teacher might have a high sense of self-efficacy to teach computer science concepts in a certain pedagogical approach, but a low self-efficacy to teach those concepts through the use and interaction with educational robotics.

Some studies developed about the concept have shown that the sense of teacher self-efficacy appears strongly correlated with the willingness to adopt new practices and methodologies in the classroom, in particular, relating to educational technologies [37]. Other studies indicate that some teachers' insecurities and fears in using ICT restrict their willingness to try them out [38], and that teachers with low ICT integration, report lower confidence in using computers [39]. According to ref. [40], teachers' attitudes towards technology influence their acceptance of its usefulness and its integration in the educational context.

As referred to in the previous section, educational robotics has great potential to improve teaching [27], however, "the gain in learning by students is not guaranteed just by the simple application of robotics, as there are several factors that can determine the outcome" [3] (p. 986) and one of the most important factors is teacher competence and self-efficacy on technologies and robotics [41]. Several studies have highlighted the importance of educational robotic activities to promote teachers' interest, knowledge, and self-confidence in STEM and in the use of robotics for teaching purposes [5,31,42].

In our research context, in-service teachers' perceived self-confidence and knowledge about educational robotics could be an important factor to improve their use in students' learning activities.

3. Methods

Research design and methodology were organized into a descriptive and exploratory quantitative approach [43] and aimed to analyze the computer science in-service teachers' knowledge, interest and, self-confidence to use educational robotics and other programable objects in classroom activities to teach computer science concepts and to promote students' computational thinking skills.

Additionally, the recommendations of the ethical commission of the Institute of Education of the University of Lisbon and the ethical guidelines for educational research were respected. The participants were informed about the purpose of the study, and the anonymity and confidentiality of the data collection and analysis were guaranteed [44]

3.1. Participants

The participants were 174 in-service computer science teachers at Portuguese public schools, 91 females and 83 males. Most of the sample are between 40 and 49 years old (92) and are experienced teachers with more than 10 years of experience (132). All the participants have a degree in computer science or in a similar area and a certification in order to be a teacher, mandatory in the Portuguese educational context. The sample was selected from two online communities of Portuguese computer science teachers.

3.2. Data Collection

The data was gathered from the participants, between December 2020 and January 2021, using the online application of the Robotics Interest Questionnaire Scale (RIQ), adapted from [41]. Permission was obtained from the original authors to adapt and use the questionnaire. The 27 items on the RIQ examined teachers' interest in robotics and technologies (Q1, Q2, Q3), problem-solving practices (Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11), working collaboratively (Q12, Q13, Q14, Q15) and self-confidence and knowledge to use robotics in classroom activities (Q16, Q17, Q18, Q19, Q20, Q21, Q22, Q23, Q24, Q25, Q26, Q27). A 5-point Likert scale from strongly disagree (1) and strongly agree (5) was used to collect the participants self-rating (Appendix A).

3.3. Data Analysis

Running the data analysis process, first, all the data was exported to Statistical Package for the Social Sciences software (SPSS v.27) to conduct the statistical analysis. An explorative factor analysis (EFA) using the principal component method with a varimax rotation was piloted using the 27 items in order to test and define the number of factors. To analyze the scale's reliability Cronbach's alpha coefficient was analyzed for the overall scale and for each dimension or subscale. Spearman's correlation analyses examined the inter-correlations among the subscales and evidence of discriminant validity. Finally, the in-service teachers' scores were analyzed by conducting descriptive statistics techniques and parametric tests (t-student and ANOVA) to examine the differences among the independent sample groups for age, gender, and teaching experience.

4. Results

Before the statistical and inferential analysis of the data, it was necessary to examine the assumptions of normality of the sample and the equality of the variances. The Kolmogorov–Smirnov test, conducted to explore the normality of each variable score, exposed a non-normal distribution to all variable distributions. In addition, the Levene's test specified that the equality of variances was guaranteed (see Table 2).

Table 2. Sample normality test (N = 174).

	Kolmogorov-Smirnov		Levene's Test	
	Statistic	**Sig.**	**Statistic**	**Sig.**
Total Score	0.14	<0.001	0.35	0.56
Interest Score	0.18	<0.001	1.17	0.28
Problem-solving Score	0.14	<0.001	2.91	0.90
Working Collaboratively Score	0.16	<0.001	0.48	0.49
Self-confidence and Knowledge	0.12	<0.001	0.10	0.92

Despite the normality test reporting a non-normal sample, it could be considered close to a normal distribution considering the sample size (N = 174). On the other hand, several authors have mentioned that even if normality is not guaranteed, parametric statistical tests are sufficiently robust and can be recommended for samples larger than 50 participants [45]. This robustness of parametric tests (*t*-test and ANOVA) is guaranteed as long as the distributions are not extremely skewed or flattened and the sample size is not extremely small. Accordingly, parametric tests were used to conduct the statistical analysis of data.

4.1. Exploratory Factor Analysis

To explore the constructs of the RIQ scale, an exploratory factor analysis was implemented with the 27 items of the scale. Previously, the Kaiser–Meyer–Olkin test (KMO = 0.93) and the Barlett's test of Sphericity (χ^2 = 3850.06; *p* = 0.000 suggest that it was appropriate to conduct an EFA analysis. In the EFA analysis, the factors with eigenvalues above 1 were

retained as well as the items with factor loading above 0.4 in each dimension of the scale (see Table 3). The analysis revealed that the explained variance of factor 1 was 26.75%, the explained variance of the second factor was 16.49%, the explained variance of the third factor was 13.57%, and the explained variance ratio of the fourth factor was 12.20%. The explained variance of the overall scale was determined as 60%.

Table 3. Results of EFA and Cronbach's Alpha Reliabilities for the RIQ Scale (N = 174).

Item	Factor 1	Factor 2	Factor 3	Factor 4
	Factor 1: Interest, Reliability α = 0.78			
Q1	0.53			
Q2	0.55			
Q3	0.55			
	Factor 2: Problem-Solving, Reliability α = 0.88			
Q4		0.70		
Q5		0.75		
Q6		0.65		
Q7		0.75		
Q8		0.66		
Q9		0.55		
Q10		0.47		
Q11		0.60		
	Factor 3: Working Collaboratively, Reliability α = 0.79			
Q12			0.72	
Q13			0.81	
Q14			0.84	
Q15			0.73	
	Factor 4: Self-Confidence and Knowledge, Reliability α = 0.96			
Q16				0.87
Q17				0.83
Q18				0.81
Q19				0.86
Q20				0.87
Q21				0.70
Q22				0.76
Q23				0.53
Q24				0.71
Q25				0.64
Q26				0.71
Q27				0.62
Eigenvalue	12.46	3.48	1.58	1.11
% of Variance	26.75	16.49	13.57	12.20
Total Variance explained = 60.00				
Overall reliability of Cronbach's alpha = 0.95				

The Cronbach's alpha reliability (see Table 3) for the overall scale was 0.95 and ranged from 0.78 to 0.96 for the four dimensions, which is an indicator of high internal consistency.

4.2. Inter-Correlation Analysis

In order to examine the inter-correlations among the four dimensions of the RIQ, the Spearman's correlation coefficient was calculated, which is used to analyze ordinal variables and non-normal distributions. The analysis of the Spearman's correlation coefficients revealed a statistically significant and positive correlation between the dimensions ($0.35 <$ rho < 0.66, $p < 0.001$). A high level of correlations was found between 'Working Collaboratively' and 'Problem-solving' (rho = 0.66; $p < 0.001$) and between 'Problem-solving'

and 'Interest' (r = 0.64; *p* < 0.001). Conversely, lower levels of correlation were reported between 'Self-confidence and Knowledge' and another three dimensions (See Table 4).

Table 4. Inter-correlations among the scores of the RIQ dimensions (=174).

	1	2	3	4
1. Interest	1			
2. Problem-solving	0.64 **	1		
3. Working Collaboratively	0.41 **	0.66 **	1	
4. Self-confidence and Knowledge	0.42 **	0.47 **	0.35 **	1

Note. ** *p* < 0.01.

According to these results, a linear regression model was defined between the dimensions with the highest correlation coefficient.

The results of linear regression of 'Interest' score as the predictor of 'Problem-solving' score specify that the participants interest in educational robotics can explain 55% of the variance in the 'Problem-solving' score and the regression model predicts a significantly problem-solving level (F(172) = 213.78; *p* < 0.001; r^2 = 0.55). Results report that each 1-point increase in 'Interest' score also increases the 'Problem-solving' score by 0.63 (b1 = 0.63; t = 4.62; *p* < 0.001).

Finally, the results of the linear regression of the 'Working Collaboratively' score as the predictor of the 'Problem-solving' score specify that the participants' 'Working Collaboratively' practices can explain 53% of the variance in the 'Problem-solving' score and the regression model predicts a significant problem-solving level (F(172) = 195.70; *p* < 0.001; r^2 = 0.53). Results report that each 1-point increase in the 'Working Collaboratively' score also increases the 'Problem-solving' score by 0.70 (b1 = 0.70; t = 13.99; *p* < 0.001).

4.3. Computer Science In-Service Teachers Scores on RIQ

To examine the in-service teacher scores on overall scale and in each dimension or subscale, the descriptive data were organized as in Table 5. It shows that, for all dimensions, the values of kurtosis and skewness are within an acceptable range considering the non-normality of the distribution [46]. The overall sample had a high level in the four dimensions range from 3.52 (Self-confidence and Knowledge) to 4.40 (Working Collaboratively) and a total score of 3.97 on a 5-point Likert type scale.

Table 5. Computer Science in-service Teaches' Scores on RIQ Scale and Each Dimension (N = 174).

Sample		Total Score	Interest Score	Problem-Solving Score	Working Collaboratively Score	Self-Confidence and Knowledge
Mean		3.97	4.29	4.29	4.40	3.52
Median		4.07	4.33	4.38	4.50	3.75
Std. Deviation		0.61	0.67	0.57	0.59	0.86
Variance		0.37	0.45	0.32	0.35	0.74
Minimum		1.56	2.00	1.75	2.00	1.00
Maximum		5.00	5.00	5.00	5.00	5.00
Skewness		−1.17	−1.19	−1.55	−1.17	−0.58
Kurtosis		1.95	1.64	3.80	1.31	−0.08
Percentiles	25	3.66	4.00	4.00	4.00	3.00
	50	4.07	4.33	4.38	4.50	3.75
	75	4.37	5.00	4.63	5.00	4.08

Further analysis explored the group differences on the participants' scores among gender age, and years of teaching experience. To analyze the gender impact in the levels of 'Interest', 'Problem-solving', 'Working Collaboratively', and 'Self-confident and Knowledge', a comparative analysis of the mean was made using an independent-sample *t*-test. Although there are differences between scores of all dimensions according to the gender,

the results of the *t*-test reported that these differences did not have statistical significance ($p > 0.05$) (see Table 6).

Table 6. Results of the *t*-test on the dimensions scores grouped by gender (N = 174).

	Gender	N	Mean	SD	*t*	*p*
Total Score	Male	83	3.98	0.60	0.25	0.80
	Female	91	3.95	0.62		
Interest Score	Male	83	4.27	0.63	−0.27	0.79
	Female	91	4.30	0.70		
Problem-solving Score	Male	83	4.23	0.53	−1.16	0.24
	Female	91	4.33	0.60		
Working Collaboratively Score	Male	83	4.34	0.59	−1.26	0.21
	Female	91	4.45	0.59		
Self-confidence and Knowledge	Male	83	3.61	0.86	1.26	0.21
	Female	91	3.44	0.86		

The results of ANOVA tests highlighted statistical significance on mean scores on overall scale and in the four dimensions grouped by the age of the participants ($p < 0.05$). Table 7 summarizes the comparative analysis of the ANOVA test and the results of the Scheffé test used to examine between which groups such differences are established.

Table 7. Results of the One-way ANOVAs and Scheffe tests on the dimensions scores grouped by age (N = 174).

	Age	N	Mean	SD	*F*	*p*	Scheffé Test *p*
Total Score	20 to 29	3	3.90	0.62	4.46	0.005	
	30 to 39	48	3.90	0.59			
	40 to 49	92	4.10	0.52			0.07
	>50	31	3.67	0.77			
Interest Score	20 to 29	3	4.56	0.51	3.84	0.011	
	30 to 39	48	4.16	0.67			
	40 to 49	92	4.43	0.59			0.032
	>50	31	4.03	0.80			
Problem-solving Score	20 to 29	3	4.25	0.50	5.83	<0.001	
	30 to 39	48	4.23	0.55			
	40 to 49	92	4.43	0.48			0.001
	>50	31	3.96	0.71			
Working Collaboratively Score	20 to 29	3	4.75	0.43	4.15	0.007	
	30 to 39	48	4.36	0.60			
	40 to 49	92	4.51	0.55			0.013
	>50	31	4.11	0.62			
Self-confidence and Knowledge	20 to 29	3	3.22	1.07	2.31	0.078	
	30 to 39	48	3.45	0.86			
	40 to 49	92	3.67	0.77			
	>50	31	3.24	1.03			

The Scheffé tests further showed that, for all dimensions, no significant differences were found between the '20 to 29' and '30 to 39' groups. However, in the dimensions 'Interest', 'Problem-solving' and 'Working Collaboratively' the results of the test reported significant differences between the '40 to 49' and '>50' groups. These findings suggest that the group aged 40 to 49 years old have higher levels of interest, problem-solving, and working collaboratively skills on educational robotics use than the other groups.

Finally, the analysis of the influence of the teaching experience (in years) on the scores of the overall variables was estimated by the One-way ANOVA test. The results

reported that the differences on scores grouped by years of teaching did not have statistical significance (see Table 8). Thus, the years of teaching experience is not a factor that promotes significant changes on the average scores presented by teachers.

Table 8. Results of the One-way ANOVAs on the dimensions scores grouped by teaching experience (N = 174).

	Year of Teacher Experience	N	Mean	SD	*F*	*p*
Total Score	0–10	32	3.77	0.59		
	11–20	96	4.02	0.58	2.66	0.072
	>20	36	4.03	0.11		
Interest Score	0–10	32	4.08	0.11		
	11–20	96	4.35	0.66	2.73	0.068
	>20	36	4.36	0.10		
Problem-solving Score	0–10	32	4.18	0.57		
	11–20	96	4.33	0.56	1.06	0.348
	>20	36	4.29	0.60		
Working Collaboratively Score	0–10	32	4.29	0.53		
	11–20	96	4.45	0.61	1.05	0.351
	>20	36	4.40	0.61		
Self-confidence and Knowledge	0–10	32	3.26	0.86		
	11–20	96	3.59	0.81	2.67	0.072
	>20	36	3.65	0.96		

In the results section, the main findings of this study were described as well as all the statistical procedures used to analyze the data collected from the participants. In the next section, the findings are discussed in relation to another related literature example according to the research objective and questions of the study.

5. Discussion and Conclusions

This study sought to analyze the levels of interest, self-confidence, and knowledge in using robotics to teach fundamental computer science concepts and promote computational thinking skills. Furthermore, we sought to analyze the participating teachers' interest in collaborative work and problem solving. As mentioned in the background section, educational robotics has been referred to in several studies as an excellent pedagogical strategy for teaching in several STEM areas, in particular in computer science. According to this perspective, it is essential to have teachers with adequate preparation and interest in using robotics in the classroom.

In this study, first the metric quality of the data collection instrument used to find out teachers' opinions about the variables under analysis was analyzed. The factorial analysis confirmed that the four factors or dimensions defined at the beginning proved to be adequate. The analysis of the scale's reliability coefficient revealed a high level of internal consistency. This proves the metric quality of the scale developed by ref. [41] and adapted to the context of this study.

To answer the first research question, the study findings report that the 174 computer science teachers have high levels of interest, problem-solving, working collaboratively, and self-confidence and knowledge to use educational robotics for teaching purposes. It is noteworthy that all scores are higher than 3.52 on a scale between 1 and 5. It is evident that this group of teachers has a high interest in developing collaborative problem-solving activities using robotics. However, it was possible to identify that the levels of self-confidence and knowledge can still be improved. The results are related to previous studies on teachers' interest, self-confidence, and knowledge to use robotics [5,9,31,47] and to promote computational thinking [34].

Teacher training programs should provide the opportunities to design and experiment with pedagogical activities with robots, without the anxiety of the real classroom. According to Fridin and Belokopytov [48], teachers show positive reactions and acceptance in using robots, in this case socially assistive humanoid robots, in pre-school and elementary school classroom activities (p. 30), and that teachers need information before practical issues are considered (p. 29), which demonstrates that training is essential before implementing activities in the real classroom.

Ertmer and Ottenbreit-Leftwich [49] report that it is imperative to provide teachers with the training opportunities that would enhance their self-efficacy in the pedagogical use of technologies. Developing teachers' knowledge and self-efficacy to use the technology can enhance their confidence to teach with technology [50] and to promote the development of their students' digital competence. In addition, these training initiatives can provide moments of collaborative work between teachers in the design and implementation of learning tasks enriched with digital technologies and robotics. Fridin and Belokopytov [48] suggest that for teachers to feel in control of technology, rich repositories of educational games should be developed (p. 30), something that can be easily accomplished in teacher training initiatives.

To sum up, these different dimensions must be considered articulately in the formative moments of the teachers [51]. Additionally, in the context of this study, the analysis of the inter-correlations (research question two) showed that the variables correlate significantly, most notably between the interest in robotics and collaborative work, and between collaborative work and problem solving. The linear regression model allowed us to understand that analyzing the participants' level of interest in robotics, science, and mathematics can predict by 55% the variation in their interest in the problem-solving strategy. Similarly, it was identified that the interest in collaborative work can predict by 53% the variation in interest in the problem-solving strategy. It is an important finding that proves the importance of taking into account these multidimensional needs in the teacher training programs on digital technologies and robotics.

Another focus of analysis was the search for evidence of significant differences in the scores presented by the teachers considering other variables such as age, gender, and years of teaching experience. For example, in some dimensions male teachers had slightly higher scores than female teachers, while in other dimensions the female teachers had slightly higher scores, however, these differences are not statistically significant. This finding is in line with the results of other studies that found no gender- and age-related differences in interest and motivation to use robotics for teaching [52]. However, in our study it was possible to identify statistically significant differences in the scores of the different variables considering age, in particular between the group of participants who are between 40 and 49 years old and the group over 50 years old. The group between 40 and 49 years old, the majority of the sample, showed higher scores in three of the four dimensions. This finding needs to be analyzed with more accuracy, in other studies and with a larger sample size, to corroborate the influence of the participant's age.

5.1. Implications for Practice

This study offers a few practical implications for teachers, teacher training institutions, and teacher training course design. First, computer science teachers should consider it necessary to invest in developing their skills, interest, and knowledge on using robotics in the classroom to enrich their students' learning experiences. Thus, they should engage in training initiatives that allow them to develop these competence levels by engaging in learning scenarios that promote the integration of robotics in an educational context. The involvement in these types of initiatives may provide the necessary educational experiences for teachers to develop their levels of self-confidence and knowledge that are so important in promoting innovation in pedagogical practices. When teachers are involved in the planning and implementing of learning activities with robotics and thinking about the

solutions, they rethink all the possible pedagogic approaches that they learned in theory and transfer their knowledge to new situations and problems [5].

A second level of recommendations is directed towards the teacher training institutions, particularly it is important to point out some important aspects to consider when designing training courses in the field of educational robotics. The main results of the study highlighted the importance of the articulation of the analyzed dimensions to promote the use of educational robotics in the classroom. Accordingly, the design of teacher education courses should provide learning experiences that promote the development of teachers' interest and knowledge, as well as provide experiences of collaborative work among teachers and sharing of practices. The results showed the importance that teachers attach to collaborative work and knowledge sharing to promote their interest and self-confidence. Finally, it is important that these initiatives are attractive to all teachers, particularly the more experienced teachers (more than 50 years old), who have shown only moderate levels of interest and self-confidence.

5.2. Limitations

Limitations of methodological and contextual nature were encountered in the implementation of this research. The small sample size, representing about 5% of the total number of computer science teachers in Portugal, does not allow us to generalize the results. However, the characterization of the sample presents many characteristics similar to the population, for example in terms of age and gender of the participants.

Another relevant limitation is related to the instrument used for data collection. The use of self-report scales presents as an advantage the possibility of collecting data on a large scale, based on the opinions and perceptions of the participants. However, it does not allow for a detailed analysis of the effective use of robotics in the classroom, only the intention and interest of the participants in its use is identified. Considering these limitations, a scale developed and validated in previous studies was selected, and it was very important to guarantee the quality of the data collection process.

Despite the study limitations, and the small context, a set of relevant results was highlighted about computer science teachers' preparation to use robotics and to support their students in learning activities with these technologies. Therefore, it is important to promote the development of the teachers' knowledge, confidence, and competence in training programs to prepare these professionals to act with robotics in the classroom. According to these limitations, several studies could be developed to analyze real classroom practices supported with robotics and how the activities impact the learning outcomes of students' skills in the computer science field, particularly in Portuguese educational context. For this purpose, some participants could be selected for a deeper analysis of their practices of using educational robotics by conducting interviews and observing classroom activities.

Appendix A

Table A1. Robotics Interest Questionnaire Scale.

Q1	I find it interesting to learn about robots or robotics technology.
Q2	I would like to use robotics to learn mathematics or science.
Q3	I would use robotics in my classroom teaching.
Q4	I like using scientific methods to solve problems.
Q5	I like using mathematical formulas and calculations to solve problems.
Q6	I think careers in science, technology, engineering or math are interesting.
Q7	I use a step-by-step process to solve problems.
Q8	I make a plan before I start to solve a problem.
Q9	I would like to learn more about careers that involve science, technology engineering, and mathematics.
Q10	I try new methods to solve a problem when one does not work.
Q11	I carefully analyze a problem before I begin to develop a solution.
Q12	I like listening to others when trying to decide how to approach a task or problem.
Q13	I like being part of a team that is trying to solve a problem.
Q14	When working in teams, I ask my teammates for help when I run into a problem or do not understand something.
Q15	I like to work with others to complete Projects.
Q16	I have sufficient knowledge about robotics for use in teaching and learning activities.
Q17	I have sufficient knowledge of coding as it applies to robotics.
Q18	I have sufficient knowledge of the engineering and design process as it applies to robotics.
Q19	I have sufficient knowledge to select the most appropriate robot to teaching and learning according to students ages.
Q20	I have sufficient knowledge to analyze the pedagogical potentialities of different type of robots.
Q21	I have sufficient knowledge about block-based programming apps that can be used to teach programming concepts.
Q22	I feel confident that I have the necessary skills to user robotics for classroom instruction.
Q23	I feel confident that I can engage my students to participate in robotic-based projects.
Q24	I feel confident that I can help students when they have difficulties with robotics.
Q25	I feel confident that I can plan and design learning scenarios with robotics.
Q26	I feel confident about teaching computer science with different type of robotics.
Q27	I feel confident that I can assess students' outcomes in robotics learning activities.

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