CBIE 2023
CONGRESSO BRASILEIRO DE INFORMÁTICA NA EDUCAÇÃO
Uma escola para o futuro: Tecnologia e conectividade a serviço da educação

Analyzing the Effectiveness of an Educational Process for Teaching Programming Through Educational Robotics in a Brazilian Technical and Vocational High School

Isabelle M. L. Souza[1], **Lívia M. R. Sampaio**[1], **Wilkerson L. Andrade**[1]

[1]Universidade Federal de Campina Grande (UFCG), Campina Grande, Brasil

isabellemaria@copin.ufcg.edu.br, {livia, wilkerson}@computacao.ufcg.edu.br

Abstract. *Problem-solving is an essential human development skill that can be fostered through Computational Thinking (CT). Programming education has been explored to develop CT in High Schools. However, teaching programming can be challenging, being necessary educational processes that improve guidelines to direct this teaching. In the past, we proposed an educational process based on methods for teaching programming with Educational Robotics (ER) and the Anthropological Theory of Didactics. However, we still need to conclude the effectiveness validation of this educational process. This study aims to evaluate our educational process's effectiveness in developing Technical and Vocational High School students' CT skills. We intend to answer the research question: RQ) How effective is the impact of an educational process of teaching programming with ER on students' CT skills in High School? The development of CT skills was evaluated through the Román-Gonzalez CT Test. The overall results indicated that the educational process is effective in teaching programming with ER impacting CT skills. This study's result contributes to the scientific community in the sense of guiding the validation of an educational process.*

1. Introduction

Problem-solving is an essential skill for human development. Computational Thinking (CT) is a modern approach to improve problem-solving skills and can be defined as a problem-solving process exploring common skills of Computer Science (Wing, 2006). Programming education has been explored to develop CT in High School. However, teaching programming can be challenging (Fu, 2021). Consequently, educational processes are essential in this context.

We proposed an educational process [Souza et al. 2022] based on methods for teaching programming with Educational Robotics (ER) and the Anthropological Theory of Didactics (Colomb, 1986). Also, we validated two educational process instances through the Delphi method (Murry and Hammons, 1995) that showed the concordance between instantiating and guidelines through experts' evaluation. However, observing the statistical aspect to define our educational process's effectiveness is essential.

This study aims to evaluate the effectiveness of our educational process to develop High School students' CT skills. We intend to answer the following research question: RQ) How effective is the impact of an educational process of teaching programming with ER on students' CT skills in High School? This study is based on a research-intervention method in two steps: (1) application the intervention on High School students submitted to our educational process; (2) analysis of the impact on the students' CT Skills. We used a sample of 93 students representing 92.1% of students who enrolled in a Brazilian Technical and Vocational High School (TV High School) in 2022.

We classified the students as experimental and control groups, according to their contact with the educational process in 2022. Each group interacted with the same programming and robotics content; however, the experimental group followed the educational process. The interventions arise between September, October, and November 2022 with a total workload of 10h, being carried out with weekly classes of 1h40min distributed over six weeks according to the school calendar.

We evaluated the CT skills development of the students through the performance in CT Test by Román-Gonzalez, before and after the intervention. We used the *Mann-Whitney test* (*U test*) (paired and unpaired) and Cohen's d effect size to answer the RQ. The unpaired *U Test* indicated a significant difference between the experimental and control groups' performance (U=12973, p-value < 0.05). The paired *U Test* showed that the experimental group presented a significant difference between their CT pre-test and CT post-test performance (U=1903, p-value < 0.05). The experimental group achieved a mean of 10.59% and a median performance of 2% better than the control group; so, we considered that the significant difference shown in all (*U test*) is positive, demonstrating that the experimental group has a better CT development. Finally, Cohen's d effect size on both groups has a smaller positive impact caused by the educational process.

Those results indicated that the educational process has effectiveness in teaching programming with ER impacting CT skills. We are working on a qualitative study considering observational data from the intervention to more precisely characterize the impact and better understand the effectiveness of the educational process.

2. Background

This section presents the fundamental concepts that are the basis of this study.

2.1. Computational Thinking

The CT idea began in 1980 with the Seymour Paper [Papert and Harel 1991, Papert 1980] studies about constructionist learning that defends developing students' thinking skills through computer science concepts. It gained visibility in 2006 when Jeannette Wing [Jeannette M 2006] recognized it as a "fundamental, not rote skills"for problem-solving in your paper published in Communications of the ACM magazine. Jeannette mentioned that CT designates a universally feasible attitude and skill that computer scientists and anyone willing to learn can use [Tekdal 2021].

Nowadays, CT has been explored in Computer Science education research, and its definition is still in progress, but there is a trend related to the problem-solving cognitive process. CT's idea relates to thinking of a computer scientist when facing problems to be solved [Jeannette M 2006]. However, CT is fundamental not only to computer scientists, but it can be applied in daily life, and is needed to adjust to the future and should be taught at early ages [Zapata-Cáceres et al. 2020]. That way, many researchers propose studies to foster CT skills or some of its skills. Some of these studies indicate incorporating CT into the curriculum at all educational levels, from kindergarten to university [Mongeon and Paul-Hus 2016, Voogt et al. 2015, Yadav et al. 2011]. In partnership with National Science Foundation and the Computer Science Teachers Association in 2011, the International Society for Technology in Education launched the Model Curriculum for K-12 Computer Science [Tucker 2003]. In High School, the CT introduction, in general, involves computing, programming, and the use of technology. Specifically, programming education has been explored worldwide to stimulate CT in High School students, becoming no longer an exclusive practice in Computer and Engineering courses [Zanetti and Oliveira 2015].

3. Educational Robotics

The ER is the learning environment that combines scrap materials or assembly kits composed of motors and sensors controllable by computers and software that operate the built models through programming [Ebenezer Takuno de and Thais Helena dos 2015]. It is still possible to define ER as the construction of the mechanism that a computer can control for an educational purpose [Viviane Gurgel de 2008]. ER research tries to understand how relations with robots can foster and support learning in humans (from young children to adults) [Alimisis 2013, Zawieska and Duffy 2015]. The ER strategies can be categorized into two goals: 1) Learning about Robots (Education in Robotics or Robotics as a Science); 2) Learning with Robots (Robotics for Education) [da Silva Petini 2018]. Also, the ER could be offered as intra-curricular or extra-curricular, according to the educational proposed goal [Mubin et al. 2013].

When considering Basic Education, ER's use involves several goals: teaching programming, teaching robotics as a science, interdisciplinary science teaching, PC development, participation in tournaments, and Olympics [Souza et al. 2021c]; offered in an intra-curricular or extra-curricular way. Although the purpose of educational practices with ER is diverse, it is possible to identify a practical nature involving problem situations, whether to teach curriculum science or programming logic [Souza et al. 2021c]. The student is engaged in "learning by doing", commonly called hands-on. In this context, students are meant to instruct the robot to perform a distinct task. Regardless of the purpose and learning strategies, there is a trend to plan, design, or implement an algorithm to control the robot's behavior to perform a specific task [Chevalier et al. 2020a], an idea directly related to solving problems from the CT Skills [Pivetti et al. 2020].

3.1. Anthropological Theory of the Didactic

The Anthropological Theory of the Didactic is research in mathematics education by Yves Chevallard that studies didactic transposition processes [Bosch and Gascón 2006, Chevallard 1989, Chevallard 1992b, Chevallard 1992a, Chevallard 1999]. For this theory, mathematics in its various dimensions is about human activities. Therefore, it is possible to apply it in different activities that favor the establishment and execution of tasks and the necessary knowledge for their accomplishment. In this theory, the object is a human activity resulting from constructed knowledge. This knowledge can be known, taught, or learned as long as different technical tasks and technologies are applied to work with them [Zanardi 2013]. The Anthropological Theory of the Didactic comprises structural (praxeologies) and functional (didactic moments). Didactic moments realization involves the praxeology constitution and its elements of the set [T, τ, θ, Θ] that, at the end of the process, it is possible to establish a relation between the Personal (X) (e.g., students and teachers) and Object (O) determined as R(X,O). This successful relation is understood as learning [Colomb 1986].

3.2. Delphi Method

The Delphi method assists judgmental prediction and decision-making in various research domains. Delphi was initially devised to help experts (judges) achieve better forecasts than they might through a formal group meeting [Rowe and Wright 2001]. The Delphi method allows for a progressive consensus to be reached on a study object. This method occurs through questioning rounds to an expert group, in which the answers are analyzed for a consensus. The consensus criteria depend on the researcher's study. However, the strictness of the consensus criteria must be respected [Williams and Webb 1994]. The main characteristics of the Delphi method are the specialist's anonymity, the statistical representation of the distribution of results, and feedback from the expert's responses for re-evaluation in subsequent rounds [Wright et al. 2000].

4. Related Work

Some studies propose a kind of educational process for some teaching [Colomb 1986, Schivani 2014, Chevalier et al. 2020b, Azman et al. 2017]. However, few have discussed how these models or educational processes are validated. As far as we know, no study proposes and validates educational processes for teaching programming through ER focusing on CT development in TV High School.

The Anthropological Theory of the Didactic [Schivani 2014] had been used by Schivani [Schivani 2014] as a tool to determine the necessary elements for didactic moments application. The author performed an intervention study in Physics teaching in High School through the ER. With this work, Schivani observes that the ER use, mainly aimed at teaching Physics, allows a comprehensive approach, whether related to theory or practice, to the two blocks of Anthropological Theory of the Didactic: practical-technical and technological-theoretical. Schivani's proposal is a methodological proposal for teaching physics with ER. In addition to proposing a methodological foundation, he applies it and presents the essential guidelines for its replication.

Our study is similar to that proposed in Schivani [Schivani 2014] because we applied or educational process built considering the Anthropological Theory of Didactic to teach students from High School through ER. However, we used the Anthropological Theory of Didactic indirectly when we applied our educational process. In [Souza et al. 2022], we showed our educational process based on the Anthropological Theory of Didactic and ER consolidated methodologies to teach sciences like LEGO® Education [ZOOM 2010], besides our ER experiences [Souza et al. 2016a, Souza et al. 2016b, Isabelle M. L. et al. 2019, Souza et al. 2021b, Souza et al. 2021c]. In this study, we described the results of an intervention that observed how high school students develop CT skills with or without contact with our educational process. Hence, with the results, which indicated that students who had contact with the educational process were more impacted, we constituted guidelines for validating educational processes in terms of quantitative aspects.

Azman and Mohamed [Azman et al. 2017] proposed an educational process to foster CT in higher education. For this, the author, from an analysis of CT research, offers an educational process based on four ideation process steps. Our study is similar to that presented in Azman and Mohamed [Azman et al. 2017] in using the ER to CT foster. However, we focused on understanding how our educational process quantitatively impacts the CT's skills to validate our proposal presented in [Souza et al. 2022]] and, consequently, contribute to the literature with guidelines that can be applied to validate educational processes. In addition, with this study, we could endorse our past studies [Isabelle M. L. et al. 2019, Souza et al. 2021b, Souza et al. 2021a] that indicated ER as an instrument capable of fostering CT skills in TV High School students.

5. Methodology

This study is based on a research-intervention method that aims to apply our educational process presented in [Souza et al. 2022] to obtain evidence that helps to understand its effectiveness and how to teach programming through ER better in the Brazilian TV High School context.

5.1. Research Design

This intervention study aims to evaluate the effectiveness of our educational process to develop High School students' CT skills. The development of this work was divided into two steps: (1) application the intervention on High School students submitted to our educational process; (2) analysis of the impact on the students' CT Skills. The following research questions and hypotheses guided the development of this intervention study:

(RQ) How effective is the impact of an educational process of teaching programming with ER on students' CT skills in High School?

- *H.0:* There is no evidence that an educational process of teaching programming with educational robotics impacts the students' CT skills in High School.

- *H.1:* An educational process of teaching programming with educational robotics impacts the students' CT skills in High School.

Table 1 presents the design for our intervention study, which the study's primary author conducted. This design consists of two student groups (control and experimental) with similar profiles. Each group interacted with the same programming and robotics content in the intervention; however, the experimental group intervention follows the educational process guidelines for programming teaching with educational robotics. The control group interventions considered traditional programming learning, i.e., the contents were shown previously in an expository way by the teacher, and after the students tried to program the robots using the contents. Some variables are part of this design:

- High School (HS): This independent variable represents the actions performed during the school year from High School;

- Educational Robotics (ER): This independent variable represents the ER use as a teacher instrument;

- Programming Teaching (PT): This independent variable represents the programming teaching;

- Educational Process: This independent variable represents the use of all guidelines and lessons proposed in this thesis proposal;

- CT Skills Performance (CT): This dependent variable represents students performance in CT tests. The CT test is from the tool or instrument to measure CT skills.

Tabela 1. Intervention Experiment Design

Groups	Independent Variable	Dependent Variable
Experimental	HS + ER + PT + Educational Process	CT1
Control	HS + ER + PT	CT2

5.2. Sample and Data Collection

This study considered a sample of 93 students from the Computing TV High School in the Paraíba state. We classified the students as experimental and control groups, according to their contact with the educational process in 2022. The control group was composed of 40.86% (38) students, and the experimental group of 59.14% (55) students. Each group interacted with the same programming and robotics content in the intervention; however, the experimental group intervention follows the educational process guidelines for programming teaching with educational robotics. The control group interventions considered other programming learning, i.e., the contents were shown in an expository way by the teacher, and after the students tried to program the ER using the contents.

To determine whether our sample of students was representative, we applied the sample size calculation in Equation 1, where n = calculated sample, N = population size, Z = standardized normal variable associated with the confidence level, p = true probability of the event, and e = sample error.

$$n = \frac{N \cdot Z^2 \cdot p \cdot (1 - p)}{Z^2 \cdot p \cdot (1 - p) + e^2 \cdot (N - 1)} \tag{1}$$

Given the size of the students' population of 101 students, the result of the sample size calculation indicates that our sample is represented with an error (the difference between estimated and real numbers) of 2.87% with 95% confidence (the probability that the useful sampling error is less than the admitted sampling error).

We conducted the data collection between September, October, and November 2022. This data collection contemplated quantitative data regarding the students' cognitive development before and after the intervention. These data were obtained by applying a *survey*, the CT Test by Román-Gonzalez *et. al* [González 2015].

The students in the experimental and control groups were from different classrooms of the target school and were randomly selected. The sample comprised 93 students, 42 (45,16%) male, and 51 (54,84%) female.

5.3. Intervention Design

The intervention consisted of three different lessons, and the CT test was applied before (pre-test) and after (post-test) the three lessons. We observed the students' CT skills from both groups before the programming lessons and after. Hence, we intended to notice the educational process's impact on the students' CT skills.

5.4. Instruments

The the CT Test by Román-Gonzalez *et. al* [González 2015] was used as an instrument to obtain the CT skills data after the intervention. The test consisted of 28 questions, spread over 12 pages, with approximately three questions each. All questions had four answer alternatives (A, B, C, and D), of which only one was correct. From the beginning of the test, participants had up to 45 minutes to answer the questions. However, it was not determined that all questions would be answered. The test[1] used was developed by Prof. Doctor Román-Gonzalez from the Universidad Nacional de Educación a Distancia (UNED) and translated/adapted by the researchers Rafael Marimon Boucinha and Christian Puhlmann Brackmann, having uses in this study duly authorized by them.

5.5. Data Collection and Analysis

The students' data were collected by applying the CT Test by Román-Gonzalez. The CT Test was applied on the same day, for 45 min, following the guidelines of the test authors, involving the control and experimental groups. Both groups were guided in advance about the structure, duration, and procedures for the test resolution. For the correction process, each question was corrected, considering that the answer could be correct or incorrect, and one point was attributed to each correct question. The result was stored in a spreadsheet.

We used the R programming language for the statistical data analysis, a graphical analysis procedure, and hypothesis tests to assess whether the parameterization of the data and guide the statistical tests were suitable. Due to non-parametric data, the *U Test* (paired and unpaired) test was chosen to evaluate if there is a significant difference between the performance of both groups (experimental and control) in CT through the CT Test result. Cohen's effect size index was used to calculate and analyze the educational process effect under the students' CT performance [Cohen et al. 2011]. In the tests, we considered a confidence level of 95%, a statistical significance of α = 0.05, and the *U Test* since we were dealing with non-parametric data. Also, the specific statistical assumptions of the test were obeyed.

5.6. Ethics Code

As this study involved human beings, it followed the resolution 196/96 of the Brazilian National Health Council. Thus, we registered this study proposal on "Plataforma Brasil"[2] under the number CAAE 90723918.5.0000.5182. Before starting the established activities, we explained to the participants about actions that would be carried out; each participant read and signed the appropriate consent terms. for carrying out this study. Besides that, we treat all data anonymously.

6. Results

To answer the research question **(RQ)**, we analyzed the mean, median, standard deviation (*SD*), mean difference, and median difference of the experimental and control groups concerning the CT observing the CT Test.

Considering the pre-test, we observed that the experimental and control groups presented similar performances, with the experimental group being slightly better than the control one, with a mean difference of 2.33% and a median difference of 0.50% higher than the control group. This data indicate that the booth group showed CT starting skills compatible. After the intervention, the experimental group achieved a mean difference of

[1]The CT test is available on: https://github.com/isabellelimasouza/CTProgER_Tese_Doutorado.
[2]Plataforma Brasil: http://plataformabrasil.saude.gov.br/login.jsf

10.59% and a median difference of 2.00% higher than the control group, data that indicated the educational process may have had a more significant impact on the experimental CT skills. Table 2 presents the performance of each group.

Tabela 2. Groups Performance From Román-Gonzalez CT Test

Test	Experimental			Control			Mean Difference	Median Difference
	Mean	Median	SD	Mean	Median	SD		
Pre-Test	14.27	14.00	4.70	13.95	13.50	4.65	2.33%	0.50%
Post-Test	16.33	16.00	4.36	14.76	14.00	4.69	10.59%	2.00%

To check the *H.0* null hypothesis (there is no evidence that an educational process of teaching programming with educational robotics impacts the students' CT skills in High School.), we performed a non-parametric hypothesis test (*Mann-Whitney U*) (paired and unpaired) applied to the two independent samples. Initially, we observed whether there was a significant difference between the experimental and control groups in CT skills after (post-test) the interventions. We applied the unpaired test (*Mann-Whitney U*) for this. The *p-value* obtained in this test demonstrated a significant difference between both groups. This significant difference in favor of the experimental group was due to the median difference (data that must be considered in non-parametric tests) that is better than the control group (see Table 3).

Tabela 3. Hypothesis Unpaired Test From Román-Gonzalez CT Test

Test	U Test	*p-value*	Confidence Level	
			Min	Max
Post-Test	12973	<0.05	0.00001539296	3.999984

In addition, to verify if there is a significant change between the preliminary and final performance on the CT test of the experimental and control groups, we applied the paired test (*Mann-Whitney U*). This test identifies the changes in the behavior of the groups distinctly, i.e., it verifies if there is a change between the pre-test and the post-test of each group individually. Then, we can see the evolution of each group statistically. The *p-value* obtained in this test demonstrated a significant difference in the experimental group's preliminary and final CT skills (see Table 4). We considered this significant difference as positive because the median from the post-test is better than the pre-test (see Table 3). However, the *p-value* obtained in this test did not demonstrate a significant difference in the control group's preliminary and final CT skills.

Tabela 4. Hypothesis Paired Test From CT Test

Groups	U Test	*p-value*	Confidence Level	
			Min	Max
Experimental	1903.0	<0.05	0.0000553709	0.0000553709
Control	786.5	0.5013	-1.9999610000	2.9999780000

According to the information presented in Tables 3 and 4, we can reject the null hypothesis with a confidence level of 95% and accept the alternative hypothesis *H.1*: an educational process of teaching programming with educational robotics impacts the students' CT skills in High School.

We also analyzed the effect of the educational process on student performance in the experimental and control groups. Calculating Cohen's *d* effect size index, we obtained

Tabela 5. Effect Size in CT From Román-Gonzalez CT Test

	Effect (d)	Effect Size
Experimental Post-Test x Control Post-Test	0.35	Small
Experimental Pre-Test x Experimental Post-Test	0.45	Small
Control Pre-Test x Control Post-Test	0.17	Insignificant

d = 0.35 (see Table 5). As d is equivalent to the tabulated *Z-score* of a standard normal distribution [Coe 2002], we have that 64% of students from the experimental group have a higher mean concerning the students from the control group. Following Cohen's definition, [Cohen et al. 2011] this effect is small, since $d \geq 0.35$.

To better understand the small effect when considering the experimental and control groups, we analyzed the effect of the interventions on the groups separately. We observed that the effect caused in the experimental group was small (d = 0.45). However, in the control group, it was insignificant (d = 0.17). Hence, despite being small, the intervention had different effects on the groups. The intervention based on the educational process had a small effect on the experimental group. In contrast, the intervention that did not follow the educational process had an insignificant effect on the control group.

6.1. Discussion

Studies show that using ER to teach programming can impact CT skills. Programming can be solitary, whereas working with ER is usually done in groups and includes social, personal, and emotional aspects[Bers et al. 2014a, Chalmers 2018]. Compared to a traditional curriculum activity in play, ER helps programming, CT development, and sequencing ability [Yang et al. 2022]. Besides, in [Souza et al. 2021b], we show that contact with computational-based ER can positively impact CT skills; however, this impact could be even more significant if supported by an educational process built to foster CT.

Validating an educational process is still challenging because it involves solving complex problems proposition to academic practice [Plomp et al. 2013]. In [Souza et al. 2022], we introduce an educational process for teaching programming in High School with ER that we considered in this study. Also, we validate two educational process instances through the Delphi method. In this study, we performed a real-world validation, considering student CT performance, to define our educational process effectiveness in a complementary way. In this sense, we conducted an intervention with two student groups from a Computing TV High School, an experimental group, which had contact with the educational process, and a control group, which had no contact with the educational process. It is essential to elucidate that both groups had contact with programming concepts through ER. This study indicates that both groups could be their CT skills minimally impacted by the contact with the teaching programming through ER. We believe that this minimal impact is assigned to teaching programming through ER, as indicated in [Bers et al. 2014b, Chalmers 2018, Yang et al. 2022, Souza et al. 2021b]. Although the experimental group showed significant statistical test results, the control group had a minimal impact on CT performance when comparing its pre-test and post-test data. Although, statistically, it was without effect. However, the difference is significant when the intervention follows the educational process, demonstrating that it may be the best way to teach programming through ER.

The existence of a better way of teaching programming through ER is strengthened in our study when we observe the size of the effect that the intervention caused in the groups. When comparing the experimental and control groups, the effect is small. However, when the effect is analyzed individually, the effect in the experimental group, considering the pre-test and post-test, is small but insignificant in the control group. We observed a small index when we compared the effects of the experimental and control groups. According to our knowledge about the ER as a tool to foster CT skills, we assign this index to the experimental group effect, which supports our understanding of our educational process validity. However, the qualitative evidence obtained during the interventions, arising from observations and interaction with students, integrates a set of subjective knowledge that cannot be quantified or statistically tested but is essential for the validation process of our educational process. The statistical data presented in this study constitutes a set of procedures that can be used quantitatively to validate the effectiveness of our educational process because there is a statistical difference between the participants who had contact with the educational process. We believe that the procedures presented by us in [Souza et al. 2022], with this study results and the subjective knowledge that we will analyze, will contribute to the scientific community in the sense of guiding the validation of an educational process.

6.2. Threats of Validity

This study has threats to validity. The CT performance data were obtained manually from Román-Gonzalez CT Test, which can generate errors due to human factors. The Román-Gonzalez CT Test questions used in the study may not be straight, interfering with student performance and the statistical test results presented. The sample analyzed is representative of the student population of the TV High School in a Brazilian public school, so we can not generalize the results to other populations. Moreover, it was impossible in this study to control factors of academic life that may influence the analysis, such as School dependences, elementary school quality, and extracurricular activities.

7. Concluding Remarks and Future Works

Intending to evaluate the effectiveness of our educational process to develop High School students' CT skills, we performed a study based on a research-intervention method considering two steps: (1) application of an intervention to apply the educational process with High School students; (2) analysis of the impact on students' CT skills.

The results highlight that the educational process built to teach programming through ER is capable of helping the student to develop his CT skills better because we observe a significant difference between the participants who had contact with the educational process. However, we can not generalize the results to other student populations since we only considered data from students enrolled in a Brazilian public TV High School. The statistical data presented in this study constitutes a set of procedures that can be used, in a quantitative way, in the process of validating the effectiveness of our educational process [Souza et al. 2022]. We believe that the procedures presented by us in [Souza et al. 2022], together with the result of this study, contribute to the scientific community in the sense of guiding the validation of an educational process.

We intend to work on a qualitative study considering observational data from the intervention to more precisely characterize the impact and better understand the effectiveness of our educational process.

Referências

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education*, 6(1):63–71.

Azman, S. M. S., Arsat, M., and Mohamed, H. (2017). The framework for the integration of computational thinking in ideation process. In *2017 IEEE 6th International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, pages 61–65. IEEE.

Bers, M. U., Flannery, L., Kazakoff, E. R., and Sullivan, A. (2014a). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*.

Bers, M. U., Flannery, L., Kazakoff, E. R., and Sullivan, A. (2014b). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, 72:145–157.

Bosch, M. and Gascón, J. (2006). Twenty-five years of the didactic transposition. *ICMI bulletin*, 58(58):51–65.

Chalmers, C. (2018). Robotics and computational thinking in primary school. *International Journal of Child-Computer Interaction*.

Chevalier, M., Giang, C., Piatti, A., and Mondada, F. (2020a). Fostering computational thinking through educational robotics: A model for creative computational problem solving. *International Journal of STEM Education*, 7(1):1–18.

Chevalier, M., Giang, C., Piatti, A., and Mondada, F. (2020b). Fostering computational thinking through educational robotics: A model for creative computational problem solving. *International Journal of STEM Education*.

Chevallard, Y. (1989). On didactic transposition theory: Some introductory notes. In *Proceedings of the international symposium on selected domains of research and development in mathematics education*, pages 51–62. Comenius University Bratislava, Czechoslovakia.

Chevallard, Y. (1992a). Fundamental concepts in didactics: Perspectives provided by an anthropological approach. *Research in didactique of mathematics: Selected papers*, pages 131–168.

Chevallard, Y. (1992b). A theoretical approach to curricula. *Journal fuer Mathematik-didaktik*, 13(2):215–230.

Chevallard, Y. (1999). L'analyse des pratiques enseignantes en théorie anthropologique du didactique. *Recherches en didactique des mathématiques*, 19(2):221–266.

Coe, R. (2002). It's the effect size, stupid: What effect size is and why it is important. In *Annual Conference of the British Educational Research Association*. Education-line.

Cohen, L., Morrison, K., and Manion, L. (2011). Research methods in education. *IEducation, Research methods. Routledge.*

Colomb, J. (1986). Chevallard (yves).—la transposition didactique: du savoir savant au savoir enseigné. *Revue française de pédagogie*.

da Silva Petini, L. O. (2018). Conhecimentos matemáticos mobilizados por alunos no desenvolvimento de projetos de robótica. *Semana da Matemática do Instituto de Matemática*.

Ebenezer Takuno de, M. and Thais Helena dos, S. (2015). Dicionário interativo da educação brasileira-educabrasil. *São Paulo: Midiamix Editora*.

González, M. R. (2015). Computational thinking test: Design guidelines and content validation. In *Proceedings of EDULEARN15 conference*, pages 2436–2444.

Isabelle M. L., S., Andrade, W. L., and Lívia M. R., S. (2019). Analyzing the effect of computational thinking on mathematics through educational robotics. In *2019 IEEE Frontiers in Education Conference (FIE)*, pages 1–7.

Jeannette M, W. (2006). Computational thinking. *Commun. ACM*, 49(3):33–35.

Mongeon, P. and Paul-Hus, A. (2016). The journal coverage of web of science and scopus: a comparative analysis. *Scientometrics*, 106(1):213–228.

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., and Dong, J.-J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, 1(209-0015):13.

Papert, S. and Harel, I. (1991). Situating constructionism. *Constructionism*, 36(2):1–11.

Papert, S. A. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic books.

Pivetti, M., Di Battista, S., Agatolio, F., Simaku, B., Moro, M., and Menegatti, E. (2020). Educational robotics for children with neurodevelopmental disorders: A systematic review. *Heliyon*, 6(10):e05160.

Plomp, T. et al. (2013). Educational design research: An introduction. *Educational design research*, pages 11–50.

Rowe, G. and Wright, G. (2001). Expert opinions in forecasting: the role of the delphi technique. In *Principles of forecasting*, pages 125–144. Springer.

Schivani, M. (2014). *Contextualização no ensino de física à luz da teoria antropológica do didático: o caso da robótica educacional. 2014. 220f.* PhD thesis, Tese (Doutorado em Ensino de Ciências e Matemática)—Faculdade de Educação ....

Souza, I., Andrade, W., and Sampaio, L. (2021a). Aplicações da robótica educacional para o desenvolvimento do pensamento computacional no contexto do ensino médio integral. In *Anais do Simpósio Brasileiro de Educaçã em Computação*, pages 44–54, Porto Alegre, RS, Brasil. SBC.

Souza, I. M., Andrade, W. L., and Sampaio, L. M. (2022). A framework for teaching programming in high school through educational robotics. In *2022 IEEE Frontiers in Education Conference (FIE)*, pages 1–9. IEEE.

Souza, I. M. L., Andrade, W. L., and Sampaio, L. M. R. (2021b). Educational robotics applications for the development of computational thinking in a brazilian technical and vocational high school. *Informatics in Education*.

Souza, I. M. L., Andrade, W. L., and Sampaio, L. M. R. (2021c). Educational robotics applied to computational thinking development: A systematic mapping study. In *2021 IEEE Frontiers in Education Conference (FIE)*, pages 1–8.

Souza, I. M. L., da Silva Rodrigues, R., and Andrade, W. (2016a). Explorando robótica com pensamento computacional no ensino médio: Um estudo sobre seus efeitos na educação. In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*, page 490.

Souza, I. M. L., da Silva Rodrigues, R., and Andrade, W. (2016b). Introdução do pensamento computacional na formação docente para ensino de robótica educacional. In *Anais dos Workshops do Congresso Brasileiro de Informática na Educação*, page 1265.

Tekdal, M. (2021). Trends and development in research on computational thinking. *Education and Information Technologies*, 26(5):6499–6529.

Tucker, A. (2003). *A model curriculum for k–12 computer science: Final report of the acm k–12 task force curriculum committee*. ACM.

Viviane Gurgel de, C. (2008). Roboeduc: especificação de um software educacional para ensino da robótica às crianças como uma ferramenta de inclusão digital. Master's thesis, Universidade Federal do Rio Grande do Norte.

Voogt, J., Fisser, P., Good, J., Mishra, P., and Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, 20(4):715–728.

Williams, P. L. and Webb, C. (1994). The delphi technique: a methodological discussion. *Journal of advanced nursing*, 19(1):180–186.

Wright, J. T., Giovinazzo, R. A., et al. (2000). Delphi: uma ferramenta de apoio ao planejamento prospectivo. *Caderno de pesquisas em administração*, 1(12):54–65.

Yadav, A., Zhou, N., Mayfield, C., Hambrusch, S., and Korb, J. T. (2011). Introducing computational thinking in education courses. In *Proceedings of the 42nd ACM technical symposium on Computer science education*, pages 465–470.

Yang, W., Ng, D. T. K., and Gao, H. (2022). Robot programming versus block play in early childhood education: Effects on computational thinking, sequencing ability, and self-regulation. *British Journal of Educational Technology*.

Zanardi, D. C. (2013). *A análise praxeológica de atividades experimentais subsidiando a elaboração de situações-problema no ensino de física*. PhD thesis, Universidade de São Paulo.

Zanetti, H. and Oliveira, C. (2015). Práticas de ensino de programação de computadores com robótica pedagógica e aplicação de pensamento computacional. In *Anais dos Workshops do Congresso Brasileiro de Informática na Educação*, page 1236.

Zapata-Cáceres, M., Martín-Barroso, E., and Román-González, M. (2020). Computational thinking test for beginners: Design and content validation. In *2020 IEEE Global Engineering Education Conference (EDUCON)*, pages 1905–1914.

Zawieska, K. and Duffy, B. R. (2015). The social construction of creativity in educational robotics. In *Progress in Automation, Robotics and Measuring Techniques*, pages 329–338. Springer.

ZOOM, E. f. L. (2010). Zoom education for life. In *Zoom for Education*.