Supporting Future Teachers to Promote Computational Thinking Skills in Teaching STEM—A Case Study

Cristina Tripon

Abstract: In recent years, teachers in various fields, such as science, mathematics, linguistics and others, have been interested in alternative learning strategies as opposed to traditional activities, in order to help students to examine their learning progress. The integration of computational thinking in teaching activities, after returning to face-to-face activities, can meet the needs of students during the COVID-19 pandemic. In this research, two samples of students in their first year of study were recruited for the teacher training program validation for computational skills in STEM education. The training model offers an explanation for the differences between the following two sets of data: the CT modules used in a substantial number of teacher workshops, and the results obtained, which are closely related to the argument that teachers can support students’ lifelong learning by developing computational thinking activities. The results related to the students’ scores may have contributed to their improvement in computational thinking skills and it could be one of the best examples of how to change the ways of learning about 21st century skills and sustainable education.

Keywords: computational thinking; STEM; teacher training; sustainable education

1. Introduction

The international community of nations has recognized the fundamental human right to education, and since 2000, it has been one of the goals of sustainable development. However, by looking at all the processes and conditions on which education is based, we can deduce that it should be recognized as a catalyst for development, due to its potential of being transformational. Education is not an end in itself, but a means of achieving a global sustainable development agenda, as evidenced by numerous cross-sectoral researches that demonstrate the importance of taking the first step in development with an emphasis on education.

In recent years, teachers in various fields, such as science, mathematics, linguistics and others, have been interested in alternative learning strategies as opposed to traditional activities, in order to help students to examine their learning progress. This process was exacerbated during the COVID-19 period, when teachers had many challenges related to the motivation and involvement of students to learn, in addition to meeting their needs to participate in face-to-face activities, when this was not possible. After this period of adaptation to online learning and assessment, the return to the old educational strategies was required, which needed to be improved by adopting other teaching strategies, combining those developed in online activities with those related to meeting the needs of students who were left in the background. These included collaborative activities, reflection, face-to-face project implementation, involvement of STEM education, integration of technology in any activity carried out and the need to streamline learning. The integration of computational thinking in teaching activities, after returning to face-to-face activities, can meet these needs of students.
2. Literature Review

2.1. Education and Sustainable Development

The World Bank formally organized the concept of sustainable development, from internationally comparable statistics on global development and people’s quality of life. These objectives were selected around five major themes (people, planet, prosperity, peace and collaborative relationships) to identify and analyze important trends and challenges of sustainable development, but also to obtain their solutions. All of these are in an interdependent relationship, with characteristics in response to changing circumstances. Other features could be acquired through the interaction of all 17 indicators, but the interest in this article is based on the feature related to education and its role within the other 16 indicators of sustainable development.

Regarding the first objective of sustainable development (no poverty), education is one of the strategies that can solve the goal of eradicating poverty indirectly, by reducing the number of women who become mothers at an early age and the number of people who support the family. Education can contribute to the development of the objective of sustainable development regarding poverty (zero poverty) by reconsidering the roles of women in society. In fact, the schooling of all women and men brings with it skills that can be the starting point in obtaining jobs, which leads to increased family income. Education is the link that makes it possible to develop certain degrees of specialization and the stronger the specialization, the higher the possible salary rewards are, in direct proportion to productivity. On average, one year of education is associated with a 10% increase in investment in earnings [1].

Thirdly, education can contribute to the third objective of sustainable development, good health and well-being, by guiding it. Education also helps to ensure a varied diet with vital nutrients. Parental education will lead to safe hygiene and health practices. In high-income countries, education helps reduce obesity [2]. A different variant of malnutrition manifests itself with the appearance of obesity, especially among children. Evidence of this can be found in Australia, Canada, Korea and the United Kingdom, in which the government provides adults (and implicitly parents) with counseling programs on healthy eating and effective weight control. These programs have been shown to work more effectively for educated people [3,4]. Health policies are often approached cautiously in this area, often forgetting that education is itself a health intervention. Educated people are better informed about some diseases, so they can take action to prevent them from the very first signs of the disease. They also tend to seek and use healthcare services more often and more efficiently. This is partly due to the fact that they can afford to spend more money in this area, are less exposed to risks and have healthy habits. Education strengthens people’s faith and confidence in the ability to achieve goals and make major changes in their lives. Most educated people tend to have healthier children [5,6]. Considering these factors, the investment in education can contribute to the achievement of objective 6 (clean water and sanitation), objective 7 (affordable and clean energy), objective 11 (sustainable cities and communities) and objective 12 (responsible consumption and production).

The quality of education is vital for economic growth. Spending more time in school, although important, is not enough [7]. Each country should monitor the learning of their students for a period long enough to assess the effects of education and its impact on economic development. In the context of the development of a competitive, knowledge-based society, the development of human capital has become a strategic priority at both a European and national level. Investments in the development of human capital in education and training are needed to strengthen the system’s capacity to respond to rapid changes in society and the labor market [8]. The report [9] revealed the glaring discrepancy between the new skills demand regarding the future of working and the educational efforts to adapt to the demand in the basic curricula and highlighted the need for a new approach. The CT research and instruction discuss the problem at length in terms of developing specific CT disciplines in and through STEM education, but with the assistance of thinking practice. The relationship between computational skills and STEM education is very closely related to
the new project-based learning environment that integrates learning as a transdisciplinary practice across different disciplines. As it can be anticipated in the previous ideas, the implications of quality education are enormous. Investing in quality education (objective number 4 of sustainable development) can help both to involve an equal distribution of genders in activities, but also to ensure decent work and economic growth (objective 8 of sustainable development).

2.2. Computational Thinking

Computational thinking is understood differently in different fields, but all agree that it is about a person’s versatility in digitisation, problem solving and relevance inside and outside the classroom. Li et al. [10] argues that students’ skills have played a pivotal role in understanding the rapid changes in the world by integrating it as a model of thinking. Related to this, many researchers [11,12] have explored the use of computational skills to build approaches and practices in educational contexts. Computational skills were defined by the International Society for Technology in Education (ISTE) as a “problem-solving methodology than can be automated and transferred and applied across subjects” [13]. Figure 1 explains the main issues with computational thinking skills.

As Fennell and al. states [14], computational thinking must be in line with transdisciplinary thinking practice over all the disciplines studied in school or as a discipline-specific way of thinking, as required by the new educational needs. The rapid development of demand for new skills and digitalisation have intensified the discussion on how CT can be integrated into and through STEM education.

Several patterns [15] of learning experience can be discerned and used to understand the CT components. There are multiple faces of CT skills, but model-based assessment refers to four stages (decomposition, pattern recognition, abstraction and algorithmic design), as presented in Figure 2 below.

The projects [16,17] explored the ways in which STEM education can be connected to CT. The analysis data were taken in stages associated with transversal skills, such as creativity and problem solving or connected to programming websites such as Scratch. Many studies [18,19] have examined computational models in many professional fields through explicit inclusion in science, technology, engineering and mathematics (including

Figure 1. Computational thinking: a holistic view.
computer science as a learning tool) or implicit inclusion in STEM education, with CT skills being part of the curricula.

![Computational thinking skills levels](image)

**Figure 2.** Computational thinking skills levels.

### 2.3. Training of Future Teachers and the Romanian Context

It can be easily observed that the emphasis on the formation and development of 21st century skills mean that the school acquires a more concrete practical and applied dimension and meets the requirements of individuals and society.

The changes that have occurred in recent years within the labor market are necessary and sufficient arguments to redefine the professionalism of teachers. This new professionalism involves the adoption by teachers of new roles, such as the facilitators of learning and co-participants in the learning process, but also the reanalysis of traditional roles of teachers, such as counseling (this role takes on new dimensions generated by the specifics of today’s students.)

Because innovative pedagogy emphasizes the role of contexts in learning, it seems that during classes, teachers can only provide contexts. In addition, this is an extremely important duty. This a new role that implies a new competence to organize and make the most of learning contexts.

Moreover, even teachers are required to have new skills that are both relational and methodological. The issue of teachers’ skills and knowledge of the discipline is another concern when using integrated approaches. Teachers are usually trained in a limited number of academic disciplines and do not feel comfortable integrating a subject into their lessons for which they have not been trained or qualified from the beginning.

The changes that have taken place in recent years in terms of the significance of learning and assessment, the integration of new technologies, the emphasis on the pleasure of learning rather than the pleasure of achieving a certain grade and the transversal skills needed in the labor market, have produced the need for real reorientation regarding the way in which a graduate of compulsory or university education is positioned.

In relation to this fact, the continuous educational reform (in Romania, the changes have been continuous for the last 30 years, with an education law that already has 70 improvements) is another reason why the investment in teacher training needs to be long term, with performance indicators and continuous educational consulting, especially to adapt the skills of future graduates to the global market.

In the context of the training of future teachers in Romania, as well as their knowledge of their school discipline, integrated approaches are taken into account. Teachers are usually trained in a limited number of academic disciplines and do not feel comfortable when
integrating a topic into their lessons for which they have not been trained or qualified from the beginning. Teaching in a team, on the other hand, can lead to conflict, increased school daytime, and content issues. Currently, teacher training is carried out within universities, through the training departments for the teaching career (the so-called psycho-pedagogical modules for level 1, which offer the possibility of teaching students in lower high school education, the Xth grade, but also the psycho-pedagogical training module II for teaching higher high school classes or at the university level). The vast majority of teachers in Romania choose this solution, as a complementary training option during their bachelor’s studies in their specialty (engineering, physics, chemistry, biology and other disciplines). In addition, since 2020, the central administration (ministry of education) has introduced specialized teacher training (until 2020, it did not exist and the training was carried out at the initial level), by organizing professional teaching masters for each domain. This was necessary to increase the quality of teachers, but also to develop a greater demand for the teaching career (this is among the last solutions from the perspective of the employability of young graduates, who prefer other fields). Regarding the development of the competences of the 21st century, at present (starting with 2017), the same Ministry of Education contributes to the development of teachers’ competences through their participation in continuous training programs. This is the first time that the central administration of education has been interested in the continuous training of teachers in order to increase the quality of education (as a result of the not very good results obtained by Romanian students in international tests). In-service training for teachers under the national CRED in Education project provides expertise in education training and evaluation, curriculum development, and curriculum design. Regarding the training of teachers from the perspective of the competences of the 21st century and of sustainable development, this does not happen centrally, but, if necessary and at the request of the teachers (who need to pay for these training courses), within the centers of professional didactic training. The current school programs within Romanian schools do not have this integrated component as compulsory; as such, there is not a very high demand in this regard from the teachers. In this context, the need for the training program proposed in the article is understandable, especially since it was carried out free of charge within the initial module of didactic training for future engineers teachers.

In the research conducted by Hodhod et al. [20], the importance of training teachers to become training mentors was underlined. The training model provides an explanation for the differences between the following two sets of data: the CT modules developed in a significant number of workshops for teachers (in teaching theories and practices of abstraction, pattern recognition, abstraction and algorithmic design) and the valuable feedback from the teachers’ experiences on applying hands-on activities with their students to design a peer assessment activity to promote an active learning environment.

The issue of introducing computational thinking programs into teacher training research was a significant obstacle in the development of computational thinking in STEM education. Using positive comments about the supported teacher training program, the researchers in ref. [21] demonstrated that computational thinking can be accomplished in content area activities, achieved by collaborative work between the teachers in the same school and re-designed personalized models for their students.

Closely related to the argument that teachers can support students’ lifelong learning by promoting computational thinking is the study by Knie et al. [22]. The fundamental conception of the paper is focused on blended-learning instructional practices to foster CT skills in the field of STEM education. The results have resulted in sustainable arguments and encouraged the introduction of CT learning modules as a part of regular professional development school programs.

Yadav et al. [23] conducted an investigation into the origins of developing programs for computational thinking in teacher training. The authors’ clarifications about the importance of incorporating computational thinking exercises into teacher training domains are developed into the following four clear recommendations: the need to adapt the teacher
education curriculum to provide clear examples of computational thinking, the need to introduce key ideas about the principle of computational thinking into all school subjects and environments, the need to develop specific strategies in the context of the specific educational discipline to provide better understanding of computational skills, the need to promote collaborative discussions between teachers and the practices in their classes, related to computational skill activities and feedback for their students and the need to use existing resources and progressively enhance peer assessment between teachers and students.

The Centre for Educational Research and Innovation [24] has conducted research on how computational thinking needs to be incorporated into mainstream teacher education and should be included directly in the core curriculum. The main reason for developing CT skills is that it leads to a better understanding of solving real problems and create valuable products, using mathematics, ICTS and digital literacy. As tutors, teachers combine experimentation, tinkering and learning by carrying out activities and contributing to a better understanding of the world and the role of students. In the study described previously, teachers reported that they combined techniques and mixed pedagogies to adopt student centered learning and practices by game-based learning and digital stories. In addition, the challenges they encountered were not simple and most teachers felt uncomfortable in terms of understanding the CT assessment or they needed continuous guidance to be informed about the new computational thinking teachers resources toolkit, a part of the CT compulsory curriculum.

The efforts to provide students with better activities have been investigated by other researchers. Katai et al. [25] conducted an investigation into the Romanian educational institutions that showed important contributions, regardless of students’ CT development. The study has shown that students using the AlgoRythmics environment have benefits such as better learning outcomes, practical applications, understanding of how the world works and how to achieve sustainable goals, and understanding of the equal importance of content and processes. Regarding the increasing arguments about including computational skills in school systems, the PISA assessment was incorporated in 2021 and included examples of computational thinking questions in the mathematics domain.

2.4. Computational Thinking and STEM Education

The article of Yang and other researchers [26] puts forward a theory that demonstrates the importance of integrating computational thinking in STEM curricula in after-school programs. The article offers an analysis of the potential impact of its integration and examples of learning activities that embedded CT skills among teachers and student participants. The results obtained emphasized more confidence in facilitating STEM learning and students’ questions about world and engineering design thinking.

The study [27] points out that computational skills are becoming more and more important in the age of the 21st century. This has led to some specific ideas in relation to STEM education and the need to integrate CT in professional development teacher programs. The same study sets out to prove that the common perspectives about CT and STEM education encourage interdisciplinary activities and these can support the development of students’ skills in the new jobs of the last decade.

The article [28] provides an illuminating discussion of how computational thinking can be used to elucidate basic principles of development in teacher education, especially in a German educational context. The study shows the importance of teachers supporting computational thinking and the need for a new approach to demonstrate its relevance to student outcomes. According to the cited investigation, digitalization affects all school subjects, so it is important to support key principles in teacher training about the new tools, methods and ways of thinking about learning and instruction.

This approach closely identifies with the work of Acevedo-Borrega [29], who carries out the scanning work about computational thinking and educational technology. The article identifies the factors that influence the decisions on the conceptual relationship that
involves the framework of CT characteristics and the pedagogical issues included in the new research work in the last five years.

In developing methods to explain the significance of introducing computational thinking measures, one can classify the ways of establishing a possible model for designing CT by combining block-based programming and physical computing devices [30]. The cited study provides examples of learning experiences and pedagogical strategies for teaching CT skills in early childhood.

3. Materials and Methods

The present study aims to develop a practical assessment of CT skills for students at university level (first year) who are preparing to be future STEM teachers. To facilitate its use with varied computational thinking strategies and activities, this assessment was designed to analyze a classical certification program targeted at teacher professional development. Thus, we designed a framework composed of 3 learning modules, with variant levels of CT skills (decomposition, pattern recognition, algorithmic design and abstraction), connected to the relevant CT concepts and proposed learning activities (Table 1: lesson plan design). For example, in Module 2, after the training session, all students belonging to the experimental group are asked to develop logical analysis, search and sorting skills to reach the decomposition level using flashcards, a game-like task-based activity (Figure 3). Also there are asked to develop collaborative activities and reason using flashcards and questions (Figure 4). In Module 3, students are asked to use mind maps to reach the level of algorithmic design skills (Figure 5). Also, after the training session, all students in the experimental group are involved in using the teacher’s examples to further investigate the changes between the test sessions (Figure 6).

Table 1. Lesson plan design.

<table>
<thead>
<tr>
<th>Description</th>
<th>Module 1</th>
<th>Module 2</th>
<th>Module 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Make sense of problems and persevere in solving problems</td>
<td>Ask questions and define problems</td>
<td>Construct viable arguments and critique reasoning</td>
</tr>
<tr>
<td></td>
<td>Reason abstractly and quantitatively</td>
<td>Analyze and interpret data</td>
<td>Plan and carry out investigation</td>
</tr>
<tr>
<td></td>
<td>Use technology and digital media</td>
<td>Engage in arguments from evidence</td>
<td>Construct explanations and design solutions</td>
</tr>
<tr>
<td>Format and time (months)</td>
<td>Whole class</td>
<td>Pairs/individual</td>
<td>Pairs/individual</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>1 month</td>
<td>1.5 months</td>
</tr>
<tr>
<td>Computational thinking section</td>
<td>Introduction to key concept</td>
<td>Decomposition data</td>
<td>Pattern recognition</td>
</tr>
<tr>
<td></td>
<td>Decomposition</td>
<td>Pattern recognition</td>
<td>Algorithmic design</td>
</tr>
<tr>
<td></td>
<td>Pattern recognition</td>
<td>Algorithmic design</td>
<td>Abstraction</td>
</tr>
<tr>
<td>Number of active participants (for each learning module)</td>
<td>90 males</td>
<td>94 males</td>
<td>96 males</td>
</tr>
<tr>
<td></td>
<td>53 females</td>
<td>54 females</td>
<td>54 females</td>
</tr>
</tbody>
</table>

In the following (Table 2: types of tasks) section, some examples of activities carried out within the training modules for teachers in order to develop computational thinking in classes of students will be selected.
Table 2. Types of tasks (examples).

<table>
<thead>
<tr>
<th>Learning Objectives</th>
<th>Materials and Resources</th>
<th>Students Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn characteristics of complex systems that relate to ecosystems</td>
<td>Chart paper collecting and graphing data</td>
<td>Discuss what abstractions exist in this model. Who are the agents, what is the environment, and what are the interactions between agents and environment?</td>
</tr>
<tr>
<td>Experience population growth and limits to growth through a simulation</td>
<td>Activity sheet “Patterns of population growth”</td>
<td>Name a characteristic of complex systems that can be observed in ecosystems.</td>
</tr>
<tr>
<td>Graph different patterns of growth and learn to distinguish them</td>
<td>Computational thinking puzzles</td>
<td>Describe and draw two growth patterns you observed. Describe what limited growth.</td>
</tr>
<tr>
<td>Learn the concept of a carrying capacity</td>
<td>Flowchart puzzles</td>
<td>Describe why a computer model might be helpful in studying ecosystems.</td>
</tr>
<tr>
<td>Make observations of the behavior of a system using a computer model</td>
<td></td>
<td>Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.</td>
</tr>
<tr>
<td>Speculate as to why computer models can be valuable scientific tools</td>
<td></td>
<td>Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.</td>
</tr>
</tbody>
</table>

Figure 3. (a) Problem decomposition through learning cards (small group); (b) problem decomposition through learning cards (pairs working).

Figure 4. (a) Collaborative activities for analyzing and interpreting data (Module 2); (b) playful task-based activity result for pattern recognition skills.
3.1. Research Participants and Procedure

The entire research group, made up of students, is part of a university with a technical specialty (with specializations in automation and computers, mechanics, distribution systems engineering, all future engineers). In addition, in relation to their previous academic background, all the participants are high school graduates, majoring in mathematics and computer science, so they all have a fundamental basis in terms of science and the way they relate to it. It is important to mention fact that, in addition to the technical specialty training, they also follow training courses to become future teachers in the STEM fields (in Romania, this can also happen during the completion of the undergraduate studies) to be able to teach students in grades V–VIII. All participants opted to participate in these courses, voluntarily, without being part of the mandatory training program for future teachers, approved by the Ministry of National Education.

Two samples of students in the first year were recruited for the teacher training program validation for computational skills in STEM education. The study group consisted of 298 students from 15 faculties of the University POLITEHNICA of Bucharest. The participants were enrolled in bachelor’s degree programs. All students are divided into 2 groups, one experimental group (applied teacher training program framework) and the control group (for compared results). At the beginning of the research, the two groups of students were divided in equal respondents, both in terms of numbers and in terms of gender, but due to the partial completion of the initial test or the partial completion of the final test, some of the respondents were eliminated from the research group. After many stages, the control group included 148 participants and the experimental group 150 students (Table 3: sample research group by gender).
All the research data obtained were fully anonymized in compliance with GDPR regulations and was also granted clearance according to the recommended Ethics Guidelines of the university to which the author was affiliated at the time of data collection. The survey included electronic consent, before research inclusion.

Table 3. Sample research group by gender.

<table>
<thead>
<tr>
<th>Sample 1 (Experimental Group)</th>
<th>Sample 2 (Control Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 96</td>
<td>Male 90</td>
</tr>
<tr>
<td>Female 54</td>
<td>Female 58</td>
</tr>
<tr>
<td>Total 150 participants</td>
<td>Total 148 participants</td>
</tr>
</tbody>
</table>

3.2. Data Collection

In the teacher training validation processes for computational skills, we used the Callysto Computational Thinking Test (CCTt), developed by Adams et al. [31,32].

The test was used in its current form, in English, as some of the teaching materials developed within the modules were distributed and used in English. In addition, all the students that participated in the research have C2 certified English language skills and also frequently use educational resources in a foreign language. However, to make sure of the complexity when testing the instrument, it was used in real time, with the teacher, so that students could ask clarification questions if needed. Before the actual use of the instrument, in its official form, the final version of the instrument was self-administered to the selected sample of respondents. Within the single constructed scale of the questionnaire, Cronbach’s Alpha was calculated to indicate scale reliability, in the sense of the equivalence of the items [33]. The value obtained for Cronbach’s alpha coefficient was 0.973, which points to very good scale reliability.

In addition, the same tool was used in the initial testing version of the computational thinking competencies, as well as in the final testing version of the improvement of the computational thinking competences for all the respondents, both those in the control group and those in the experimental group (those who participated in the training modules described above).

The Callysto Computational Thinking Test (CCTt) is composed of 6 pillars, as described in Table 4 (pillars of research instrument). All the indicators presented in Table 3 were used both for the initial testing of the entire research group and for the final testing, in order to be able to identify the initial level of the students’ computational skills and the level developed after participating in the training modules (by experimental group).

Table 4. Pillars of research instrument used.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Item Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital literacy</td>
<td>4 Likert-scale items with statements such as “I find it easy to use technology” and “People ask me for help with their computer”.</td>
</tr>
<tr>
<td>Computational thinking test</td>
<td>5 Likert-scale items, 4 teacher-specific Likert items with scenario-based context and statements such as “When I am solving a complex problem, I try to break it up into smaller problems” and “When I am solving a complex problem, I think about what makes my solution better or worse than other solutions”.</td>
</tr>
<tr>
<td>Data Literacy</td>
<td>3 Likert-scale items with statements such as “I would rather explore data myself than have someone tell me what it means”.</td>
</tr>
<tr>
<td>Previous coding experience</td>
<td>4 Likert-scale items; open-ended question with statements such as “I am comfortable writing code to solve problems” and “Describe your experience with coding and/or computational thinking. Please list what languages and/or tools have you used ...”.</td>
</tr>
<tr>
<td>Problem solving items</td>
<td>3 Open-ended questions</td>
</tr>
<tr>
<td>Spatial CT items</td>
<td>10 multiple choice items</td>
</tr>
</tbody>
</table>
4. Results

The general goal of the research is to measure the effects obtained by the target group in terms of developing computational thinking skills as a result of their participation in a semi-annual course of computational thinking within sustainable development. This desideratum is realized on the basis of an experimental type of research, with a control group (for which no intervention is carried out in any way) as well as an experimental group (which involved intervention with the help of the training course for future teachers). Both groups are tested with the same research tools.

In order to verify the research hypothesis regarding the results of the future teachers who participated in the training modules for the development of computational thinking, we will analyze both the experimental group, comparing the results obtained in the stage before the participation in the computational thinking courses with the results obtained after participating in the described courses. In the second part, the results obtained will be analyzed, by comparison, between the control group (the subjects did not participate in any training program for the development of computational thinking competences) and the experimental group, which involved intervention through the biannual course of computational thinking.

The results, compared with the sample group (experimental group), are presented in Table 5 (computational thinking score before and after teacher training programs (three modules) and results from experimental group (ANOVA). These indicate that the computational thinking teacher program was efficient for future teachers, but not at an equal level, so in different ways. Students from the experimental research group improved computational thinking skills scores, after participation in the three modules of learning activities. Pattern recognition was the highest score that future teachers in STEM education could perform the best (post-test mean 2.90), followed by abstraction (post-test mean = 2.87) and decomposition (post-test mean 2.53). In terms of the development after training session, the algorithmic design was the aspect that had the highest percentage of change (19.23%), followed by abstraction (12.33%), decomposition (12.22%) and finally, pattern recognition (8.98 %). The intervention was assessed with a questionnaire administered before and after teaching. The results recorded improvements from 8.98% to 19.23% (mean improvement of 15.38%).

<table>
<thead>
<tr>
<th><strong>Computational Thinking</strong></th>
<th><strong>Mean</strong></th>
<th><strong>Standard Deviation</strong></th>
<th><strong>Mean Difference</strong></th>
<th><strong>Percentage Change</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Decomposition</td>
<td>Pre-test: 2.17</td>
<td>Pre-test 0.83</td>
<td>0.37</td>
<td>12.22</td>
</tr>
<tr>
<td></td>
<td>Post-test: 2.53</td>
<td>Post-test 0.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pattern recognition</td>
<td>Pre-test 2.8</td>
<td>Pre-test 0.82</td>
<td>0.27</td>
<td>8.98</td>
</tr>
<tr>
<td></td>
<td>Post-test 2.90</td>
<td>Post-test 0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algorithmic design</td>
<td>Pre-test 1.90</td>
<td>Pre-test 1.05</td>
<td>0.60</td>
<td>19.23</td>
</tr>
<tr>
<td></td>
<td>Post-test 2.53</td>
<td>Post-test 0.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstraction</td>
<td>Pre-test 2.47</td>
<td>Pre-test 0.9</td>
<td>0.42</td>
<td>12.33</td>
</tr>
<tr>
<td></td>
<td>Post-test 2.87</td>
<td>Post-test 0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Pre-test 8.70</td>
<td>Pre-test 2.40</td>
<td>1.74</td>
<td>15.38</td>
</tr>
<tr>
<td></td>
<td>Post-test 11.03</td>
<td>Post-test 0.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order to verify the statistical differences of the results obtained by the experimental group, between the two pre-test–post-test moments, we apply the ANOVA test. As can be observed, the previous table (Table 5) presents the standard averages and deviations for the variable CT (computational thinking) for each of the working groups, both at the pre-test and post-test moment. In order to verify the increased effect produced by the training of future teachers, it is necessary to check the condition of sphericity, one of the conditions for
the application of the ANOVA test repeated measurements. Since the Mauchly $W = 0.770$ test result is statistically insignificant, we can confirm that the condition of sphericity met.

Table 6 is the main table of the output, containing the results of the general F tests. As $F = 306.801$, with $p = 0.00$ being significant, it suggests that there are significant differences between the three conditions regarding the development of computational thinking competence. In order to find out between which of these conditions there are differences, we apply post-hoc tests, namely Bonferonni.

Table 6. CT tests of within-subject effects.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Itself.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT research group</td>
<td>Sphericity assumed</td>
<td>6912.079</td>
<td>5</td>
<td>1382.416</td>
<td>306.801</td>
</tr>
<tr>
<td></td>
<td>Greenhouse–Geisser</td>
<td>6912.079</td>
<td>3.334</td>
<td>2073.058</td>
<td>306.801</td>
</tr>
<tr>
<td></td>
<td>Huynh–Feldt</td>
<td>6912.079</td>
<td>3.860</td>
<td>1790.518</td>
<td>306.801</td>
</tr>
<tr>
<td></td>
<td>Lower bound</td>
<td>6912.079</td>
<td>1.000</td>
<td>6912.079</td>
<td>306.801</td>
</tr>
<tr>
<td>Error (CT experimental group)</td>
<td>Sphericity assumed</td>
<td>608.296</td>
<td>135</td>
<td>4.506</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greenhouse–Geisser</td>
<td>608.296</td>
<td>90.025</td>
<td>6.757</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huynh–Feldt</td>
<td>608.296</td>
<td>104.230</td>
<td>5.836</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 shows the results of the contrast tests, which are significant between the pre-test and post-test times for the experimental group ($F = 650.699$, $p = 0.000$) and the control group ($F = 359.670$, $p = 0.000$). There are indeed other tests, but their selection is made according to the degree of interest in certain data manifested in the research conducted. Therefore, the hypothesis of the research is confirmed and the development of computational thinking skills is improved by going through the training modules.

Table 7. CT tests of within-subject contrasts.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Itself.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT research group</td>
<td>Pre-test exp.gr.-post-test exp.gr.</td>
<td>3108.036</td>
<td>1</td>
<td>3108.036</td>
<td>650.699</td>
</tr>
<tr>
<td></td>
<td>Post-test exp.gr.-pre-test.control gr.</td>
<td>3421.080</td>
<td>1</td>
<td>3421.080</td>
<td>609.016</td>
</tr>
<tr>
<td></td>
<td>Pre-test.control gr. vs. post-test. control gr.</td>
<td>7.509</td>
<td>1</td>
<td>7.509</td>
<td>1.094</td>
</tr>
<tr>
<td>Error (CT experimental group)</td>
<td>Pre-test exp.gr.-post-test exp.gr.</td>
<td>128.964</td>
<td>27</td>
<td>4.776</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test exp.gr.-pre-test.control gr.</td>
<td>151.670</td>
<td>27</td>
<td>5.617</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-test.control gr. vs. post-test.control gr.</td>
<td>185.241</td>
<td>27</td>
<td>6.861</td>
<td></td>
</tr>
</tbody>
</table>

The results of the post hoc tests (Bonferonni) show that there are significant differences between the pre-test condition and the post-test condition (Bonferonni $t = 25.51$, $p = 0.000$), between the pre-test group condition and the pre-test condition control group (Bonferonni $t = 0.0520$, $p = 0.000$), between the post-test condition of the experimental group and the control group pre-test condition (Bonferonni $t = 26.674$, $p = 0.000$), between the post-test condition of the experimental group and the post-test test control group (Bonferonni $t = 25.51$, $p = 0.000$), between the pre-test control group condition and the Bonferonni experimental group post-test ($t = 26.67$, $p = 0.000$), between the post-test control group condition and the Bonferonni experimental group post-test ($t = 25.51$, $p = 0.000$). There are no significant differences between the pre-test condition control group and the post-test control group (Bonferonni $t = 1.04$, $p = 1000$).

It can also be emphasized that both the experimental group and the control group, at the time of pre-test, developed the competence of computational thinking approximately equally, but in the post-test phase, the results no longer show this. The results obtained
in the post-test stage of the experimental group show values much higher than in the pre-test, which proves to us that the activities carried out within the modules had the expected results.

Knowing that in the post hoc tests (Bonferroni), it turned out that there are significant differences between the pre-test and post-test conditions in terms of working groups, it is necessary to calculate the size of the effect. We calculated the effect size with the formula $r = \sqrt{\text{F}}/(\text{F} + \text{dfR})$, where $r$ is the result of the contrast test $F$ and dfR means no subjects (1). The results obtained for the pre-test and post-test conditions of the experimental group are the following: $r = \sqrt{\text{650.699}/(650.699 + 27)}$ and $r = 0.96$, a very good effect in terms of anticipated improvements.

The results related to students’ scores may have contributed to their improvement in computational thinking skills and it could be one of the best examples of how to change the ways of learning about 21st century skills and sustainable education.

The report OECD Future of Education and Skills 2030 [34] warned, long before initiating the changes in education that arose from the COVID-19 pandemic, the need to integrate technology and develop transferable skills in mainstream schools. Among the three pillars mentioned, one of them is related to cognitive and meta-cognitive skills, which includes critical thinking, creative thinking, learning-to-learn, computational thinking and self-regulation.

It is important to note that these modules were built by mixed teams of teachers, researchers, curriculum and evaluation experts, online instructional design experts and programmers. Without their joint involvement, the course may have had only disciplinary perspectives, as is currently the case with the training of teachers in the STEM field. This first possible sign of change, with the change in decision and autonomy, will be implemented this fall, with the change in the laws of education (a fact that is in the final decision-making process at the time of writing the article).

Limitations and Future Research

We cannot ignore the limits of research and the variables that define it derive from many factors that we cannot identify and control for many reasons, which are as follows:

1. The dispositions, interests and motivation of students for the activities in which they are involved.

2. The research results are part of a small group of students and it is necessary to pilot a much larger number of subjects for results that can be transferable to other ages.

The identified strengths, but also the obtained products, can be capitalized in the form of the needed educational reform or as a point of development of the school’s curriculum. The learning modules developed include both elements of training and assessment methodology, ensuring key points of direct applicability in the classroom, with modules that can be selected according to interests, initial level of students, motivation to achieve certain contents, sustainable education contents within the global reform for sustainable development and contributions to the clarification of the terms and concepts used.

5. Conclusions

Today, schools no longer hold the monopoly in the formation of the young generation, but take on new dimensions that arise from the complex problems of the world in which we live, including technology, globalization, universal communication, multiculturalism and sustainable development.

Teacher’s roles and responsibilities are diversified and nuanced in relation to the new demands that come not only from the school environment, from students with new aspirations, new worldviews and life, but also from the social environment, from the community where the school exists.

If we add to all this the society under the auspices of continuous modernization, we will have a much broader vision of the complex mission of the school and of the teachers. This is all the more important because most specialists demonstrate the discrepancies that
exist between generations of teachers and generations of students. Teachers have to face specific demands of today’s society and with generations of students that are increasingly different, they have to think of ways of relating to students. This is because the current knowledge and communication-driven society requires competences that cannot be formed by teachers who do not have them (as is the case with computational thinking skills).

The integration of computational thinking into the teaching of all disciplines, especially within those in the STEM category, seems to be ‘common sense’ or have ‘validity’ because in real life, knowledge and experience are not separated into distinct disciplines. Usually, this line of argument emphasizes that the limits of traditional disciplines do not reflect the current needs and that scientific research itself is becoming increasingly integrated and interconnected. On the other hand, it emphasizes the process of building knowledge. Teaching using a global approach and creating connections between different disciplines are understood as processes that lead to new ways of thinking that connects different skills, develops critical thinking and forms the ‘complete picture’ and deeper understanding of learning.

Lederman and Niess [35] even argue that students who benefit from integrated approaches within the sciences develop a less fundamental and conceptual understanding because certain subject-specific subjects are covered in less detail or are even omitted. The teaching of the real-context sciences (STEM) emphasizes the philosophical, historical or social aspects of science and technology, as well as the connection of scientific understanding with the experiences of everyday students. This approach is considered by some researchers to increase students’ motivation to engage in scientific studies and to possibly lead to improved scientific outcomes and the assimilation of long-term learning to create useful products, develop new approach strategies and solve the problems of the present world. Both the teaching of context-based sciences and the science-technology society (STS) approach include the experiences of everyday students and contemporary social issues, such as ethical or environmental issues, and should develop their critical thinking skills and social responsibility. STS science courses aim to promote practical utility, human values, as well as a connection with personal and social issues, taught from a student-centered orientation. The purpose of science education is to make future students responsible citizens who understand the interactions between science, technology and society.

The current situation in Romanian education is defined by an important number of blockages and crises that need to be solved. One of these is the adaptation and reorganization of school programs, which were last revised in 2016, according to the European standards and subsequent development of children’s development, society and labor market characteristics. The curriculum is theocratized and inapplicable, full of age-inappropriate specialized terms, uninteresting and oriented towards the past content, designed without space to adapt and allowing evaluation through direct reproduction, without participation motivated by an interest in knowing the students. At the time of the article, new legislation is under debate regarding the training of teachers in STEM fields, the development of a new curriculum for compulsory education, to keep up with both science and technology, as well as new structural changes in terms of the purpose and roles of compulsory education and the new skills required by the labor market.

In order to support the importance of teacher training to face the challenges posed by the labor market, it is important to invest in their continuous training. There are multiple studies that provide better examples to improve students’ participation in solving real world problems [36] and computational thinking and that demonstrate the role of well-trained teachers in teaching these high order thinking skills. One of the directions of action presented is the work of Kaya and others [37,38]. The researchers argued that CT teaching efficacy beliefs can increase CT instruction in elementary classrooms. The interventions reported improved scores in the context of STEM education teachers and this choice may positively influence their future students. Li [39] argued that CT competence cannot be achieved simply by teachers developing CT-embedded curricula and lessons, and
suggested exploring experts’ views on CT education regarding challenges and solutions for better teaching techniques. Using interviews, the results obtained were integrated into some key teaching principles, such as flexibility, good instructional design (scaffolding, learned-centered methods, and a deep understanding of them), including the partnership between all teachers involved in the school to better understand the students’ needs and school context, and better school investments regarding logistic issues. Yadav [40] and others stated that CT skills will be better implemented in schools when teachers that enter the educational system are able to use a national elementary toolkit to help them organize learning in the first stages of teaching. The European Commission [41] focused, in a recent report, on the directions of action in terms of curriculum organization, teachers and assessment in order to increase achievement and motivation in mathematics and science learning in schools. An example included a framework proposed for providing learning support in mathematics and science, in every European country’s education system.

Despite the mentioned limitations, the study proposed a reliable model that can be used to assess future teachers’ CT skills from a sustainable perspective. The results show that the empirical data were in agreement with the proposed model, offering a good starting point to foster CT skills in STEM education.

Finally the analysis confirms that applying optimal training strategies that translate into practice help to ensure future teachers’ CT skills, as well as support their career development.

Petousi and Sifaki [42] combined 3742 publications to achieve a number of recommendations that addressed the research integrity/research misconduct. The same authors reported three types of factors that are necessary for building trust and confidence in science (individual factors, institutional/organizational factors and structural factors).

Moreover, all the results of the research obtained deserve to be analyzed and disclosed to the public in order to increase trust in science and to validate evidence-based changes in education. The relationship between science and society is all the more important in order to create the necessary change or reform context and must be explained in a personalized way to the general public. Science can be a solution and can play an important social role in driving innovation, sustainable development and adaptive learners in the global economy, as Krishna [43] argued. From this point of view, the present research article can improve decision-making systems through cooperation between science, learning and innovation.

Funding: This research received no external funding.

Institutional Review Board Statement: The ethical approval for the study was obtained from the Institutional Review Board, approval number 10807/07.06.2021.

Informed Consent Statement: Informed consent was obtained from all the subjects involved in the study.

Data Availability Statement: Due to confidentiality agreements with the participants, this study’s data are available only upon request from the author.

Acknowledgments: We are grateful to the students at University POLITEHNICA of Bucharest for the survey responses.

Conflicts of Interest: The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References


6. Viedeman, A. Education for Sustainable Development in Higher Education Rankings: Challenges and Opportunities for Developing Internationally Comparable Indicators. Sustainability 2022, 14, 5102. [CrossRef]

7. OECD. Equity and Quality in Education: Supporting Disadvantaged Students and Schools; OECD Publishing: Paris, France, 2012. [CrossRef]


13. Barr, V.; Stephenson, C. Bringing computational thinking to k-12: What is involved and what is the role of the computer science education community? ACM Inroads 2011, 2, 48–54. [CrossRef]


28. Özdinç, F.; Kayă, G.; Mumcu, F.; Yıldız, B. Integration of computational thinking into STEM activities: An example of an interdisciplinary unplugged programming activity. Sci. Act. 2022, 59, 151–159. [CrossRef]
42. Petousi, V.; Siakaki, E. Contextualizing harm in the framework of research misconduct. Findings from discourse analysis of scientific publications. *Int. J. Sustain. Dev.* 2020, 23, 149–174. [CrossRef]