

# Computational Thinking and Coding for Student Creativity and Innovation Capability

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## Abstract

*According to the current European policy strategy digital skills are relevant for the creation of an inclusive digital society which benefits from the digital single market. These policies foresee the training of European citizens' digital skills with several initiatives such as the skills agenda for Europe with the aim to help Europe's growth in an increasingly digital society.*

*However, the disparity between male and female participation in ICT sector is getting more marked at a professional level.*

*Therefore, one of possible solutions for overcoming this gap and to promote ICT careers is to introduce innovative methodological learning interventions which can favour, further, the development of students' problem solving and their digital potentialities.*

*In this context, the promotion of computational thinking (CT), as a support for development of the thinking ability in young people becomes fundamental. This allows students to exploit their creativity and innovation capability through the coding activities which makes computational thinking concepts more concrete and turns them into the tool for an effective learning.*

*The paper describes the project "Coding4Girls", co-funded by European Commission under Erasmus+ Programme, aiming to create and validate a learning framework for coding skills development in primary and secondary school's 10-16 years old students through the design and development of awareness raising serious games in different countries: Slovenia, Greece, Turkey, Italy, Croatia, Bulgaria and Portugal.*

**Keywords:** *STEM, Design Thinking, Computational Thinking, Serious Games, Inquiry-based learning.*

## 1. Introduction

According to the National Center for Education Statistics in the US, women represent just 18% of the university graduates in computer science. Whereas in the top universities, this number falls to 14% [1]. Computer science is the only STEM field in which female participation has dropped [2], reflecting the fact that even as enrolment increases, the number of male participants increases faster than that of women. And the disparity between male and female participation in computer science continues at the professional level: 80% of top-level employees in Silicon Valley are male and only 10% of the technical positions are occupied by female [3]. According to the report of European Commission, in Europe the situation is even worst: "Of 1,000 women with a Bachelors or other first degree, only 29 hold a degree in Information and Communication Technologies (ICTs) (as compared to 95 men), and only 4 in 1000 women will eventually work in the ICT sector" [4]. These statistics are in striking contrast with the exploding demand for computer science graduates for fuelling the software services industries that deliver solutions for a wide range of needs in today's and tomorrow's technology immersed society.

Worth to note, a EU study reports that bringing more women into EU digital sector would bring €9 billion annual GDP boost [5]. However, there is currently a shortage of computer science skilled personnel and companies in digitalizing business environment face difficulties in finding employees with the required ICT skill set [6].

In response to the above outlined challenges CODING4GIRLS project addresses an open, inclusive and innovative education and training embedded in the digital era by targeting programming skills that are in high demand in a technology driven society. The project aims to close the gender gap by effectively addressing computer science skills in the late basic school years and on the first years of secondary school, which is the time when many students lose interest in computer science and promoting equal opportunities between girls and boys in the highly rewarding computer science careers.

Moreover, by dealing with misperceptions and attitudes of learners, teachers, and parents towards computer science careers and their benefits to both girls and boys, projects demonstrates its links to real-life and highlights the fact that such careers are rewarding independently of gender or background.



## 2. Computational thinking for creativity and innovation capability

Recognized as a fundamental competency for the contemporary world [7], CT is related to the thought processes involved in formulating a problem and expressing its solution in a feasible form to be effectively carried by computer-human or machine [8]. Therefore, as a reasoning process, it should be considered independently from the use of technology. In addition, it could be referred to as a different way of “problem solving” requiring specific abilities related to the problem definition, data analysis and logical organization; models and simulation development for data visualization; an effective combination of resources to reach possible solution found and to be applied to different contexts and situations [9].

The continuous grow of the scientific data we facing today will inevitably require an appropriate application of different kinds of such computational abstractions as algorithms, data and control structures, logics and semantics etc. Being focused on the process of abstraction, and, in this regard, being ideologically close to the mathematical reasoning, CT can be regarded as the evolutionary successor of the last, but with an essentially enhanced complexity of the problems potentially treated. In fact, whereas mathematical formulation of interdependence between entities is basically represented by a formula or a set of equations, computational methods, apart from being the fundamental auxiliary tools for the first, are capable to provide a much more flexible and advanced instrument to embrace the behavior of systems of different complexity and scale, where a purely mathematical formulation is incomplete. Moreover, numerical methods, for example, sometimes are the only ones that permit a certain mathematical problem to be solved [10].

Thus, given the ever-increasing quantity and complexity of the scientific data from one side and the enormous potential of computational approaches, the creativity and, as a consequence, innovation capacity of the 21<sup>st</sup> century will naturally proceed side by side with ones’ capability to formulate the problem and develop its’ solution in terms of CT abstractions [11].

As to the methodology, teaching community has already started to develop an appropriate background for the CT strategies’ entering the formal institutional curricula. The problem has already been elaborated when exploring the association between CT skills and academic performance [7], investigating the study of C Language Program Design course based on CT [12], developing the computational creativity exercises [13] and games making to promote learning in computer science and creative programming in higher education [14], [15]. In addition, given the multi- and transdisciplinary character of CT mindset, educational robotics, being purely multidisciplinary as well, have already been considered when applied jointly [11, 16, 17].

Proven to be regarded as an emerging psychological construct and a new ability that has entity of its own [18], the practitioners of the CT skills development have already proposed the number of the tools and scales for their acquiring assessment [19-21] as well.

Among the five basic technologies to teach and learn computational skills outlined in the review [18], only one out of five, known as unplugged activities, is implicitly related to the algorithmic thinking capacity development, while the resting four – explicitly.

Therefore, the coding activities represent an essential methodological tool in terms of CT skills development and are used as the basic one within the context of the CODING4GIRLS project described below.

## 3. Project’s premises

At the core of CODING4GIRLS is a design thinking pedagogical approach that is heavily linked to human-centred solutions. This approach challenges the learners to see the big picture before designing a detailed solution, encourages them to consider wider community interests, and challenges them to think entrepreneurially on how ICT can address real-world problems. This way it will also be possible to demonstrate the relevance of the field to real life.

The project introduces interventions that address the factors leading girls to avoidance of computer science career, namely: a) misperception of the roles and professional careers; b) lack of interest in the discipline and c) insufficient skills.

Recognizing the importance that teachers and the social environment of learners can play in the choice of a learner’s academic and career choices, CODING4GIRLS will further build teacher capabilities and positive perceptions and attitudes in relation to the participation of girls in computer science. The project will develop educator support content for integrating computer science related activities into instructional practices. Outcomes will be evaluated in Greece, Turkey, Italy, Slovenia and Portugal to provide a European perspective on the relevance, acceptance, and effectiveness of project methodologies and tools in diverse school, social, and business environments.



At the last stage CODING4GIRLS will validate the proposed learning framework through the design and software implementation of awareness raising serious games. Learners will be encouraged to design and code games that address specific world needs or issues. A “low entry high ceiling approach” will allow learners to start with easy problems encouraging continued participation through more challenging tasks. Learners will then be presented with “half-baked” scenarios in which a solution to an actual problem will be partially ready challenging learners to finish the implementation by developing small and manageable modules.

### 3.1 Project’s main target groups

Firstly, the project helps build the necessary background among school learners that will enable them to succeed in their future endeavors either academic (in tertiary or other continuing education in computer science) or professional (in vocational or professional activities related to computer science). Secondly, CODING4GIRLS will also address the development of teacher competencies and the profile of the teaching profession by empowering educators to effectively build desirable computer science skills among their learners. It further enables educators to lead initiatives that promote perspectives of gender equality in the pursuit of academic or professional paths in science.

Being multidisciplinary by nature, project activities require an expertise on learning requirements analysis, pedagogical design, specifications, software development, and the organization of evaluation activities, which, inevitably results in a diversified partnership.

### 3.2 Methodological learning framework development

Based on the analysis of the status quo and the state-of-the-art on how technology-enhanced learning can promote the development of programming skills a learning framework will be designed. The framework will exploit “design thinking” approaches that encourage learners to think innovatively and critically and to take into account user needs. As a result, this learning methodology is very well suited for the development of programming skills for the ICT sector among young boys and girls. Through the proposed design thinking learning methodology learners will be exposed at an early age to processes applied by the ICT sector.

The methodology will be validated through the design and implementation of serious games based on scenarios inspired by real-world needs to which learners will introduce solutions. The proposed methodologies and proof-of-concept tools will be evaluated in real-life contexts through the engagement of external groups of learners and teachers in several countries. To ensure impact, results will be widely disseminated to stakeholders, including learners, educators, policy makers, and the general public.

### 3.3 Instructional support content

Instructional support content (ISC) targets educators and aims at providing the necessary how-to good practice instructions that will allow them to integrate the proposed learning methodologies and tools into their already well developed instructional practices. More specifically, ISC aims to:

- Facilitate the more effective adoption of project outcomes on developing programming skills among girls through serious games into wider, blended learning school practices;
- Provide teachers with the information they need for enhancing their teaching on programming through the proposed serious games approach and design thinking learning methodologies;
- Help build teacher skills, confidence, and motivation in the deployment of emerging ICT, and specifically serious games, as a complementary learning tool;
- Build the skills of teachers on the integration of ICT into instructional practices through supporting content.

## 4. Conclusion

A widespread discrepancy of gender participation in coding related careers has already triggered a number of initiatives, e.g. [22-24], aiming to promote and help girls to proceed with their tech careers. CT, in this regard, and a design thinking are promising methodological approaches capable of providing a viable pathway towards tech careers motivation and engagement at youth, and girls in particular.

The project CODING4GIRLS, described in the article, represents a joint effort of different academic and non-academic entities, in the development of methodological learning framework for building programming skills among young girls (and boys). The novice of the approach, used in the project, is the application of design thinking and serious games development. Currently the works on the project are at the stage of the didactics material development and its preliminary validation based on a

corresponding strategy identifying the specific output success indicators in terms of effectiveness, quality, and completion

The continuous nature of the evaluation, previewed by the project, will ensure that the input of stakeholder representatives will be taken into account during the design and implementation process of the proposed tools and methodologies thus ensuring that the final result addresses real educational needs in terms of building programming skills among girls and boys.

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