Computational Thinking Integrated within a Social Robot Project

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Abstract. This case study explores the integration of computational thinking into the mandatory STEM curriculum in Flanders. It investigates the execution of the 'Social Robot' project in three separate classes within the Flemish education system, each representing a distinct study track. These tracks include general education with a strong emphasis on STEM, vocational education with a STEM focus, and vocational education without a specific STEM focus. Initial findings reveal variations in student interest, autonomous motivation, and self-efficacy among these three classes. In contrast to students in vocational education classes, those in the general education class display a heightened interest, perceiving the project as both more challenging and engaging. This case study provides valuable insights into the intricacies of integrating computational thinking within STEM education, emphasizing the necessity for customized computational thinking initiatives, and underlining the importance of infusing creativity and real-world relevance to enhance student motivation and learning outcomes.

Keywords: computational thinking · STEM · physical computing · Flanders · Belgium · K-12 · education.

1 Introduction

1.1 Computational Thinking and Integrated STEM

Since September 2019 minimum goals[3] on computational thinking (CT) and STEM (Science, Technology, Engineering, and Mathematics) have been part of the compulsory curriculum in Flanders. One way to address these objectives is by integrating CT into STEM projects. The integration of computational thinking within STEM subjects is driven by the recognition of the fundamental importance of STEM competencies for economic growth and the preparation of the future workforce to meet the challenges of global competitiveness [1].

[3] https://onderwijsdoelen.be, in Dutch

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Equally important, CT is a way of understanding and acting upon the digital world; a basic skill in CT enhances one's ability to understand and interact with technological developments, which can counteract the fear of technology [2].

Integrated STEM education (iSTEM) has emerged as a way to remove the perceived barriers between the four disciplines, enabling pupils to understand the relevance of STEM to address real-world technical and societal issues. Introducing CT into compulsory education aims that pupils acquire the skills of CT and to explore what they mean for the various disciplines [3, 4].

However, the successful implementation of iSTEM education is a multifaceted endeavor that extends beyond mere parallel teaching of these subjects [5]. This challenging task is an obstacle many teachers experience in adopting an integrated STEM methodology [6, 7]. Furthermore, teaching CT and programming presents its own set of challenges for educators [8, 9]. Some teachers tend to choose ready-made assignments that often lack opportunities for open-ended experimentation that are characteristic of iSTEM pedagogy but far more challenging to coach [10]. As integrating CT into STEM projects is new for many teachers, the 'Social Robot' project was developed.

1.2 Social Robot Project

The 'Social Robot' project aims to address the new learning objectives on CT and STEM through an exciting theme that also incorporates learning goals on privacy and societal issues. The implementation of the project was carried out by high school teachers instructing pupils in grades 9 or 10; the pupils were in different fields of study within both general and vocational education. The overarching goal was to empower teachers to navigate open-ended problems and enhance their confidence in the domain of physical computing. Simultaneously, pupils had the opportunity to engage in a programming task that stimulated their creativity and imagination, and prompted them to contemplate the applicability of their work in real-world contexts. To support the teachers, a comprehensive set of resources[4] was made available, such as online materials designed to provide insights into the cutting-edge realms of social robotics and human-robot interaction (HRI) [11]. The teachers harnessed a customized robotics kit, allowing their pupils to collaboratively build personalised social robots.

1.3 Our Study

Given the relatively recent introduction of CT within the Flemish education context, there is a limited understanding of how pupils and teachers perceive and experience CT when integrated into STEM projects like the 'Social Robot' project. This case study seeks to fill this knowledge gap. Following research questions serve as guiding pillars for our endeavor, shaping the direction and focus of our study:

[4] https://www.dwengo.org/en/socialrobot

1. How do high school pupils perceive and experience the integration of CT in the context of the 'Social Robot' project?
2. To what extent do high school teachers feel prepared to implement CT as part of iSTEM projects, specifically within the 'Social Robot' project, and what challenges do they encounter in the process?
3. What are the key lessons learned from the implementation of CT within iSTEM education, and how do they inform the future development of CT initiatives?

2 Methodology

In line with our research questions, we have adopted a mixed-methods approach. This approach allows us to triangulate findings and gain insights from both qualitative and quantitative data sources. In this study, we have two key participant groups. Five high school teachers with diverse subject expertise that actively took part in the 'Social Robot' project. A total of seventy-two high school students all of whom participated in the 'Social Robot' project.

2.1 Instruments and Analysis

Surveys: We administered surveys to high school pupils to gauge their perceptions, experiences, and motivation in relation to CT within the project. The survey included questions regarding their CT competencies, levels of interest, and perceived impact on their understanding of CT and STEM principles. Semi-Structured Interviews: High school teachers who have implemented the 'Social Robot' project were interviewed to provide qualitative insights into their experiences. These interviews explored the challenges faced, their level of preparedness for CT integration, and their observations regarding pupils' engagement. The survey instrument employed in this study has been previously validated in a separate research effort [12]. Given the relatively small sample size in this study, our analysis primarily relies on descriptive statistics, correlation values, and qualitative analysis. These analytical methods enable a comprehensive exploration of the collected data. The semi-structured interviews conducted with the participants were meticulously transcribed and subjected to qualitative content analysis. This approach allows for in-depth exploration of the interview data, unveiling nuanced insights and perspectives. Both the survey data and interview data are integrated in our analysis.

3 Results

Table 1 presents partial results from our study: data from pupils in three classes: one in general education and two in vocational education and training (VET). The class in general education is situated in a science field, thus STEM. The first VET class is also in a STEM domain, while the second VET class belongs to a non-STEM field.

Table 1. Pupils' Self-Reporting on the 'Social Robot' Project.

Constructs	**Classes** (VET non-STEM)	**(General STEM)**	**(VET STEM)**
Interest in STEM (1-4)	2.25	3.38	2.92
Confidence in STEM (1-4)	2.67	2.90	3.16
Abstraction (1-5)	3.22	3.08	3.04
Decomposition (1-5)	3.67	2.75	3.22
Pattern recognition (1-5)	3.00	2.88	3.39
Generalisation (1-5)	3.67	3.56	3.36
Algorithmic thinking (1-5)	3.00	3.38	3.39
Evaluation (1-5)	3.08	3.94	3.61
Autonomous motivation (1-4)	2.63	3.09	3.08
Controlled motivation (1-4)	2.13	2.91	2.63
Amotivation (1-4)	2.42	1.50	2.25
Fun project (0-10)	3.00	8.00	6.78
Interesting project (0-10)	4.00	8.25	6.44
Difficulty project (0-10)	4.67	5.50	3.22

4 Discussion and Conclusion

Our preliminary findings reveal notable variations in the perceptions and experiences of high school pupils in the Flemish education system as they engage with the integration of CT within the 'Social Robot' project. Importantly, the study indicates that pupils' interest STEM varies: specifically, pupils in the general education class exhibit a higher level of interest, while the non-STEM pupils express the least interest. The pupils in the non-STEM class also show the least self-efficacy in STEM.

On average, pupils from all three classes perceive their CT competencies similarly. If we look closer at the concepts of CT, we see that STEM pupils find decomposition more difficult than algorithmic thinking, while for pupils in the non-STEM class it is just the other way around. However, a noteworthy observation is that pupils in the general education class may underestimate their abstraction and pattern recognition skills, potentially linked to their greater exposure to abstract thinking. This underscores the need to ensure that pupils are aware of their own CT competencies and highlights the significance of accurate self-assessment. Autonomous motivation seems to differ between pupils in the STEM classes and the ones in non-STEM: the pupils in the non-STEM class show lesser autonomous motivation than their peers in STEM. The pupils' interest in the project corresponds to their overall interest in STEM. The pupils in non-STEM seemed to not like the project, which stands out considering the creativity and social aspects in the context of the project. Notably, pupils in the general education class rate the project as more challenging than their VET peers. This observation may be associated with the potential gap in technical skill training. However, these pupils find the project more fun and interesting, suggesting a nuanced relationship between challenge and engagement. This finding emphasizes the importance of tailoring CT and STEM initiatives to align with the diverse interests and backgrounds of students across study tracks. In conclusion, these findings highlight the multifaceted nature of CT integration in STEM education, emphasizing the need for a holistic approach. It is important to note that the qualitative nature of this study means that the results cannot be generalised to broader populations. However, the insights gained have generated valuable knowledge that warrants further in-depth research.

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