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Assessing the Effectiveness of STEM Enrichment Programs: A Comparison between Switzerland and Germany

Abstract

In this paper, we outline the data collection of a pilot study conducted in the summer 2024, aiming at addressing the gap in the literature regarding the impact of STEM (Science, Technology, Engineering, and Mathematics) enrichment programs with a primary focus on computational thinking across diverse educational and cultural contexts. While existing research has highlighted the effectiveness of such programs on cognitive and psychological factors, much of the evidence remains limited to context-specific studies. This project aims to compare two distinct educational systems one in Graubünden, Switzerland ("i-Camps" at the University of Teacher Education of Graubünden) and the other in Thuringia, Germany (Student Research Center Jena). The goal is to compare how these programs influence students' psychological and cognitive outcomes. By providing insights into how enrichment programs focusing on computational thinking impact students across varied educational environments, this project takes an important step toward filling a significant gap in comparative research within STEM education.

Introduction

In recent years, enrichment programs for STEM education have gained significant importance. There is increasing interest in literature investigating the impact of STEM enrichment programs on psychological factors, such as learners' attribution patterns, interests, self-efficacy, and self-concept, as well as their academic gains (e.g., Chiang et al., 2022).

The main objective of this project is to empirically investigate the impact of enrichment programs, particularly those focusing on computational thinking, on students' psychological and cognitive constructs. Consistent with established literature (e.g., Zindel, 2022), computational thinking in this context is distinct from programming. It includes processes such as problem-solving, important in both mathematics and computer science education. Specifically, this project aims to examine two programs offered by the "MINT-Zentrum" of the University of Teacher Education of the Graubünden (PH GR; program "i-Camps") and the "Schülerforschungszentrum Jena" (SFZ; program "Robot relay race"), each designed to foster computational thinking and engage students actively in mathematics and computer science. These programs are tailored to the educational contexts of the Canton Graubünden and the

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federal state of Thuringia, aligning with a broader definition of STEM enrichment program that includes digital tools and emphasizes computational thinking (e.g., Su & Yang, 2023).

Considering the “i-Camps” of the PHGR and the “Robot relay race” of the SFZ Jena as enrichment programs, the project aims to address three main research questions: (1) How do PHGR “i-Camps” and SFZ Jena “Robot relay race” enrichment programs influence students' attribution patterns, interests, self-efficacy, and self-concept in mathematics and computer science? (2) How do the PHGR “i-Camps” and SFZ Jena “Robot relay race” enrichment programs influence students’ performance, particularly in computational thinking? (3) How do the effects of the STEM enrichment programs differ between the educational contexts of Graubünden and Thuringia?

In this paper, we present the findings and observations from an initial validation pilot study conducted in Jena to assess the effectiveness of the instrument designed for a larger-scale data collection scheduled for 2025. The results offer valuable insights for refining the methodology, identifying potential areas for improvement to ensure the robustness of the upcoming study. The findings provide preliminary insights into children's problem-solving skills in computational thinking, as well. The content and pedagogical approaches of the “Robot relay race” enrichment program will be presented during the conference.

Methodology

Sample: The pilot study sample consists of 42 sixth to tenth graders participating in in the " Robot relay race" program by SFZ Jena.

Materials: The study utilizes an instrument comprising a range of validated scales to assess the key constructs of interest (e.g., Benölken, 2013, Geitel, 2020). Participants responded to a total of 7 tasks, covering variables such as interest (2 tasks), self-efficacy (1 task), self-concept (2 tasks), and attribution patterns (2 tasks). Additionally, participants answered 10 tasks designed to evaluate their competencies in computer science, with a focus on computational thinking, adapted from Komm et al. (2022) and from Serafini (2025).

Procedure: The study involves a test aimed at evaluating the instrument intended for the larger-scale data collection scheduled for 2025. Data collection comprises a single phase, establishing baseline measurements for all psychological constructs and subject knowledge. This phase took place in Jena in July 2025.

Data analyses

This pilot study evaluates the instrument designed to assess informatics competence and psychological constructs for a planned larger-scale data collection. The analysis investigates the reliability of the Instrument, including ten multiple-choice tasks designed to assess informatics competence, as well as seven tasks measuring psychological constructs. Moreover, it examines how children performed on the informatics competence.

Preliminary results

In the initial phase of the analysis, the internal consistency of the psychological constructs was assessed using Cronbach's alpha for each set of items. The results demonstrated acceptable to excellent reliability, with Cronbach's alphas of .70, .74, .87, .88, and .86 for the constructs of self-concept, interest, and self-efficacy. Notably, the items related to the construct of attribution patterns were not scaled, as they were presented in a multiple-choice format. These findings suggest that the items within each construct are sufficiently reliable for further analysis. Moreover, reliability for two constructs could be further improved by excluding subitems with negatively worded formulations that required recoding during the analysis, resulting in adjusted Cronbach's alphas of .74, .74, .91, .88, and .86. Additionally, the 10 items assessing computational thinking yielded a Cronbach's alpha of .83, indicating strong internal consistency.

Next, we analyzed children's performance on the 10 items assessing computational thinking. On average, children scored 74%, with a maximum score of 90.5% and a minimum of 33.3%. Two items emerged as particularly challenging. The first, solved correctly by 64% of students, involved the concept of a "switch" in algorithms. Fifteen students struggled with this task, which required finding the largest number from four digits by applying a series of three switches between neighboring digits. Some participants approached the task as a purely mathematical problem, disregarding the switching rules, and simply created the largest number from the given four digits. The second challenging item, solved correctly by only 33.3% of students, focused on the concept of "loops" in algorithms. Nineteen students completed the task without applying the required number of loops, indicating a gap in understanding this fundamental concept in computer science.

Discussion

Overall, the designed instrument was found to be reliable. The analysis revealed that children generally demonstrate an adequate level of problem-solving skills, excelling in some questions more than others. To further enhance the instrument, the results suggest removing two subitems from the psychological construct scales to improve internal reliability.

The results indicate that the concepts of "switch" and "loop" present significant challenges for students. For instance, in mathematics, reordering the digits 1368 to achieve the maximum value of 8631 requires just two switches. However, when restricted to switching adjacent digits, six switches are needed. Similarly, many students struggled with the "loop" task, failing to apply the required number of iterations. This suggests a gap in their understanding of these foundational computer science concepts and emphasizes the need to strengthen both the practical applications and conceptual comprehension of "switches" and "loops" concepts in educational programs.

The programs, such as PHGR “i-Camps” and SFZ Jena's “Robot relay race” are particularly valuable in providing insights into how these activities influence children's psychological constructs and computational thinking skills over time. Furthermore, this project plays a crucial role in addressing a significant gap in comparative STEM education research by exploring how enrichment programs impact students across diverse educational settings.

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