IMPACT: An Unplugged Board Game to Introduce Programming Concepts in Primary Education

Janine Trütsch, Larissa Meyer-Baron and Bernadette Spieler
Zurich University of Teacher Education, Switzerland

janine.truetsch@phzh.ch
larissa.meyer-baron@phzh.ch
bernadette.spieler@phzh.ch

Abstract: Fundamental programming concepts and Computational Thinking (CT) are not sufficiently covered in early primary education in Switzerland, particularly in grades 3 and 4. This gap makes it challenging for students to grasp programming when first introduced in grade 5, as they lack foundational knowledge in sequences, loops, conditions, and events. Without structured exposure to these concepts at an earlier stage, students often struggle with understanding programming logic and syntax when transitioning to coding environments. The IMPACT project addresses this issue by developing an unplugged board game that introduces key programming principles in an engaging and age-appropriate way. Following the Educational Design Research (EDR) approach, the game was developed in an iterative process that involved structured literature review, expert interviews with teachers, and feedback from didactic specialists. The first prototype was evaluated with didactic experts before testing in primary school settings to ensure its pedagogical suitability. The game is designed to be both intuitive and scalable, allowing students to progress through different levels—starting with simple movement commands and advancing towards more complex programming structures such as nested loops, conditional statements, and event-based actions. In the initial qualitative research phase, four teachers participated in semi-structured interviews to explore their expectations, challenges in teaching computational concepts, and potential classroom applications of the game. Their insights were instrumental in refining the game mechanics, ensuring alignment with curriculum goals, and improving usability for both teachers and students. Findings from the second interview (after the game had been played in class) indicate that teachers appreciate the game's accessibility, adaptability, and effectiveness in preparing students for future programming lessons. Future research will focus on quantitative analysis, extended classroom testing, and further iterations of the game. Additionally, teaching materials and training modules for educators will be developed to support broader implementation. The findings contribute to discussions on game-based learning approaches in computational education, offering practical insights into how unplugged activities can be effectively integrated into the early curriculum.

Keywords: Unplugged learning, Programming concepts, Computational thinking, Game-Based learning, Educational design research

1. Introduction

In Swiss primary education, there is a significant gap in the systematic introduction of fundamental programming concepts, particularly in grades 3 and 4. While cycle 1 focuses on basic cognitive and procedural skills such as sorting objects and following rules, many students face challenges when transitioning to formal programming in grade 5, as key concepts like loops, sequences, and conditions are not introduced early enough. This often leads to difficulties in understanding programming logic, a lack of confidence, and decreased motivation (Curzon et al., 2019; Huang & Looi, 2021).

Targeted preparation during grades 3 and 4 could lay a stronger foundation for successful programming instruction. Especially effective are unplugged and game-based approaches, which introduce programming principles in age-appropriate and motivating ways (Huang & Looi, 2021; Curzon et al., 2019). The IMPACT project addresses this gap by offering a playful and age-appropriate learning environment that builds computational foundations through an unplugged board game. It targets students in grades 3 and 4 and aims to prepare them for more complex programming instruction by engaging them in problem-solving, planning, and reasoning activities. The project situates itself at the intersection of informatics education, Educational Design Research (EDR), and game-based learning, with a distinct focus on equity, accessibility, and scalable classroom integration. Unplugged approaches were chosen deliberately to ensure broad access without reliance on hardware or digital infrastructure. Unplugged activities have emerged as an effective approach to teaching computational thinking and programming concepts in primary schools, especially where digital resources are limited (Brackmann et al., 2017; Caldwell & Smith, 2017). This educational intervention not only introduces fundamental programming concepts (sequences, loops, conditions, and events), but also supports early cognitive structuring of programming logic, fosters computational thinking, and scaffolds learning before the introduction of syntax-based environments such as Scratch. The initial phase (June–December 2024) resulted in the development and classroom testing of a board game prototype, showing high engagement and

positive learning potential. A next phase will build on this work, with specific emphasis on optimizing the game and preparing it for broader dissemination and evaluation in diverse school settings.

In this paper, we introduce IMPACT+, an unplugged board game designed to teach core programming concepts to grade 4 students. The paper is structured as follows: Section 2 outlines the pedagogical background and design rationale. Section 3 describes the methodology, including the Educational Design Research approach and classroom implementation. Section 4 presents initial findings from the classroom pilot. Section 5 discusses future development steps, including refinement, hybrid extension, and planned transfer studies. Section 6 concludes with reflections on educational impact and scalability.

2. Background

The IMPACT+ game provides a scaffolded, analogue introduction to core programming concepts before learners actually begin coding. This approach is expected to reduce cognitive load, support mental representation of programming structures, and increase problem-solving efficiency.

The project developed a board game in which two to four players control avatars across a game board using command cards (see Fig. 2). The objective is to collect coins placed at the corners of the board and score as many points as possible. In each round, players first plan their moves using the game board (see Fig. 1), then execute their sequence of actions. The game ends when the golden key is revealed. The game includes several levels, starting with simple movements and advancing to conditions and complex loops, thereby covering programming concepts such as loops, conditions, sequences, and events.

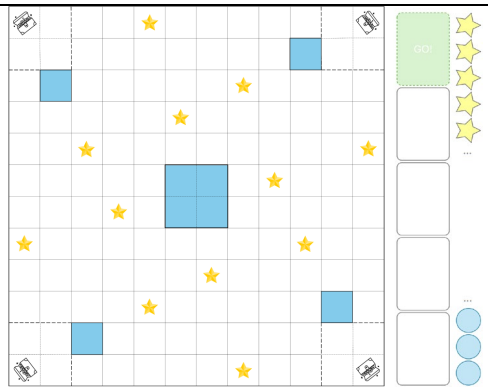


Figure 1: Game board

Figure 2: Game cards

The game is structured into progressive levels that gradually introduce core programming concepts. Table 1 summarises the content and function of each level, including available command cards, loop mechanisms, and conditional logic elements.

Table 1: Gaming Levels

Level 0	**Command cards:** Turn 90° left Turn 90° right Move forward 1 field Back of all cards: GO + Collect objects
Level 1	**New gaming cards:** 1-step loop (repeat 2x / 3x / 4x): use template and place it over the card to be repeated.
Level 2	**New loop templates:** 2-step loops (2x / 3x / 4x): same principle, templates have space for 2 cards Loops can also be nested **New gaming card:** Trun 180°
Level 3	**New loop templates:** 3-step loop (2x / 3x / 4x): same, templates hold 3 cards

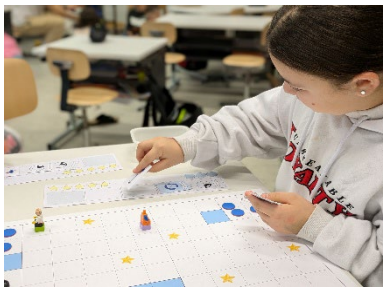
Level 4	Use portals (conditions/variables): If two stars, then you may use the portal
Level 5	**New gaming cards:** Repeat until edge / obstacle / treasure chest: same principle
Pro level	**Pro Level – New game cards and loop templates:** 4-step loop (2x / 3x / 4x): same (for advanced players), templates hold 4 cards

3. Methodology

The game was developed and evaluated in two phases using an Educational Design Research (EDR) approach (Plomp, 2013). A structured literature review included analysis of existing games (e.g., Tsarava et al., 2019). Expert interviews were conducted with four teachers who later participated in the classroom pilot. Their feedback was incorporated into the subsequent development phase. The prototype was then tested by two didactics experts. Their feedback led to further refinement of the game prior to the intervention phase. Before testing in the classroom, participating teachers submitted demographic data on their students via Excel. The Educational Design Research (EDR) approach chosen (Plomp, 2013) is particularly suitable for the practical development and testing of educational innovations. Combining literature research, expert interviews, subject-specific didactic assessment and classroom testing enables an iterative development process.

The intervention in class lasted three lessons and took place directly at schools. In the first two lessons, students played the prototype version (see Figs. 3–5). In the third session, focus group interviews with students were conducted. Teachers also participated in a guided post-interview. Additionally, students completed an online questionnaire based on the Game Experience Questionnaire (GEQ; Poels et al., 2007), administered shortly after the intervention with teacher support.





Figures 3-5: Classroom experiences

3.1 Sample

A total of 161 grade 4 students from eight classes in the cantons of Zurich and Schwyz participated. Recruitment took place via flyers in teacher networks and oral invitations during continuing education events. Parental consent was obtained prior to participation.

3.2 Data Collection Instruments

The expert interviews followed a guide (Helfferich, 2022) that gathered teacher expectations, requirements, and classroom context for the didactic game. Teachers also described their students' play behaviour and discussed possible classroom integration of the unplugged game.

The focus group interviews with students also followed a structured guide. Students were divided into groups of four and asked about their learning, game incidents, challenges, strategies, improvement suggestions, and visual design ideas. One group was interviewed directly by the research team.

The student survey was conducted online using Microsoft Forms and based on the GEQ (Poels et al., 2007) to assess game experience.

The teacher post-interviews focused on game observation, mechanics, clarity, design, learning effect, feasibility (e.g., prep time, organisation), and suggestions for revision or expansion.

4. Results

Several data sets were collected from the prototype evaluation:

- Qualitative data from audio recordings of student focus group interviews

- Quantitative survey data on game experience
- Qualitative data from teacher post-interview recordings

Initial insights: While final data analysis is still pending, several initial findings can be reported:

Implementation was successful in all classes. Students understood the rules and could play independently or with minor support. The physical design—coins, cards—was appealing. Game mechanics functioned well, e.g., the balance of card types, board size, and coin quantity supported progress and achievements. Three out of six levels were tested during the pilot.

Teachers gave consistently positive feedback in interviews. They found the game age-appropriate and noted observable learning effects. All participating classes kept a prototype and all teachers expressed interest in using the game again.

5. Future Work

Building on the positive feedback and initial evaluation results, several follow-up initiatives are planned to further develop and scale the project. A comprehensive analysis of the rich dataset, collected through classroom observations, interviews, and surveys, will be conducted using both qualitative and quantitative methods. These findings will guide targeted revisions. The analog prototype will continue to undergo iterative development. Game mechanics, level structures, and the visual design will be refined, and additional programming concepts such as variables or event chains may be introduced to broaden the learning potential (Tsarava et al., 2018; Chen et al., 2023). A hybrid version of the game is also in development. This will include a narrative-driven digital layer, offering contextual support without being essential to gameplay. Elements such as onboarding sequences, explanatory prompts, and a timer will enhance user guidance (Metwally et al., 2021; Poels et al., 2007; Nishida et al., 2009). To support broad implementation, printable game components and editable templates will be made available as Open Educational Resources (OER). These will be complemented by teacher guides, optional challenges, and lesson ideas to enable flexible use in different classroom settings. This aligns with current calls for accessible and curriculum-aligned resources in informatics education (Huang & Looi, 2021; Grover & Pea, 2013). The next classroom study will involve 2–4 classes to test the hybrid version's usability, clarity of narrative elements, and pedagogical effectiveness. Insights from this phase will inform the next design iteration. Finally, a future research phase (phase 3) will explore how unplugged learning with the game facilitates the transition to visual programming environments such as Scratch. A comparative study will evaluate the learning gains of students with and without prior unplugged experience.

6. Conclusion

IMPACT demonstrates how unplugged, game-based learning can effectively introduce core programming concepts at an early stage, addressing a critical gap in primary education. By combining structured gameplay with progressive challenges, the board game fosters computational thinking and supports cognitive readiness for later programming instruction. The strong engagement observed during the classroom pilot, along with positive teacher feedback, confirms the game's relevance and age-appropriateness. With its low-threshold, scalable design and upcoming hybrid extension, IMPACT contributes not only to more equitable access to informatics education but also to current research on early computing and educational game design. Future work will build on these results through systematic evaluation, iterative development, and empirical studies on learning transfer.

Ethics Declaration: All participation was voluntary and conducted with parental consent.

AI Declaration: This paper is based on a previously written German-language interim report from the IMPACT+ project. AI tools (specifically DeepL and ChatGPT) were used to support the translation and linguistic refinement of the English version. All content, structure, and academic arguments were developed by the authors.

References

Brackmann, C. P., Román-González, M., Robles, G., Moreno-León, J., Casali, A., & Barone, D. (2017). Development of computational thinking skills through unplugged activities in primary school. In Proceedings of the 12th Workshop in Primary and Secondary Computing Education (WiPSCE '17, pp. 65–72). Association for Computing Machinery. https://doi.org/10.1145/3137065.3137069

Caldwell, H., & Smith, N. (2017). Teaching computing unplugged in primary schools. SAGE Publications, Inc., https://doi.org/10.4135/9781473984332

Chen, P., Yang, D. and Metwally, A.H.S. et al. (2023) 'Fostering computational thinking through unplugged activities: A systematic literature review and meta-analysis', International Journal of STEM Education, 10, 47. https://doi.org/10.1186/s40594-023-00434-7

Curzon, P., Bell, T., Waite, J. and Dorling, M. (2019) 'Computational Thinking', in Fincher, S.A. and Robins, A.V. (eds) The Cambridge Handbook of Computing Education Research. 1st edn. Cambridge: Cambridge University Press, pp. 513–546. https://doi.org/10.1017/9781108654555.018

Helfferich, C. (2022) 'Leitfaden- und Experteninterviews', in Baur, N. and Blasius, J. (eds) Handbuch Methoden der empirischen Sozialforschung. Wiesbaden: Springer VS. https://doi.org/10.1007/978-3-658-37985-8_55

Huang, W. and Looi, C.-K. (2021) 'A critical review of literature on "unplugged" pedagogies in K-12 computer science and computational thinking education', Computer Science Education, 31(1), pp. 83–111. https://doi.org/10.1080/08993408.2020.1789411

Metwally, A.H.S., Chang, V. and Abou-Shouk, M.A. (2021) 'Revealing the hotspots of educational gamification: An umbrella review', International Journal of Educational Research, 109, 101832. https://doi.org/10.1016/j.ijer.2021.101832

Nishida, T., Kanemune, S., Idosaka, Y., Namiki, M., Bell, T. and Kuno, Y. (2009) 'A CS unplugged design pattern', in Proceedings of the 40th ACM Technical Symposium on Computer Science Education (SIGCSE '09). New York: ACM, pp. 231–235. https://doi.org/10.1145/1508865.1508951

Plomp, T. (2013) 'Educational design research: An introduction', Educational Design Research, pp. 11–50.

Poels, K., de Kort, Y.A. and IJsselsteijn, W.A. (2007) D3.3: Game Experience Questionnaire: Development of a self-report measure to assess the psychological impact of digital games.

Tsarava, K., Moeller, K. and Ninaus, M. (2018) 'Training computational thinking through board games: The case of Crabs & Turtles', International Journal of Serious Games, 5(2), pp. 25–44. https://doi.org/10.17083/ijsg.v5i2.248

Tsarava, K., Moeller, K. and Ninaus, M. (2019) 'Board games for training computational thinking', in Gentile, M., Allegra, M. and Söbke, H. (eds) Games and Learning Alliance. Cham: Springer International Publishing, pp. 90–100. https://doi.org/10.1007/978-3-030-11548-7_9