The Solothurn Project — Bringing Computer Science Education to Primary Schools in Switzerland

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ABSTRACT

Currently Switzerland is going through a major reform in its education system. One of its most ambitious and important goals is the inclusion of Computer Science Education already on the primary school level, an important measure in achieving the establishment of an information society. Such a reform raises questions about the appropriate types of approaches to be developed and employed for an effective implementation of Computer Science Education concepts in Swiss primary schools. To this end, the project “Scalable Game Design Solothurn” was developed and evaluated. This project both trained teachers and exposed students to Computational Thinking concepts through the two Computational Thinking Tools AgentSheets and AgentCubes online. Results show that teaching Computational Thinking through Scalable Game Design is not only feasible on the primary school level but also enjoyable, with AgentSheets and AgentCubes online proving to be sustainable and effective tools for the implementation of Computer Science Education on this school level. Further analysis of the data enables us to make recommendations regarding optimal ways of implementation for the Swiss reality and point towards new research directions.

Keywords

Computer science education, Computational Thinking, primary schools, professional teacher development, experience report.

1. INTRODUCTION

The omnipresence of information and communication technologies (ICT) in our everyday lives and the continuously increasing demand for an ICT-skilled workforce [8,4] arguably require the introduction of ICT education in schools. And yet, Computer Science (CS) is not a mandatory subject at any school level in Switzerland. The Swiss education system is challenged to improve this situation. To that end, the Swiss Federal Council has adopted the “Digital Switzerland” strategy and proclaimed the promotion of Computer Science Education (CSE) as an important measure to achieve the goal of establishing an information society in Switzerland [6,7].

A first important step towards that goal is the *Lehrplan 21* (LP 21),¹ the new common curriculum for compulsory education in the 21 German-speaking cantons. LP 21 was developed in order to implement article 62 of the Federal Constitution of the Swiss Confederation, which states that the compulsory school system should be harmonized.² Apart from shifting the focus away from pure content onto the learning of competences, LP 21 importantly introduces CSE on the primary school level by way of the module “Medien und Informatik”.³ The important next step is to find ways to successfully implement the rather abstract and vague module descriptions of LP 21 in practice, and bring CSE to primary schools in Switzerland. This paper is an experience report describing the CSE project “Scalable Game Design Solothurn.” This project aimed at integrating the field of CSE into selected classes using the two Computational Thinking Tools AgentSheets and AgentCubes online in the canton of Solothurn. This paper discusses the project’s successful impact and based on the assessment of the data gathered, makes recommendations about an effective CSE inclusion in the Swiss education system.

1.1 Swiss K-12 Computer Science Education

Currently, ICT education in Swiss schools mainly stands for learning to use applications like Microsoft Office. While there are many innovative teachers that teach topics beyond that, most of them do this all on their own initiative. If a student is exposed to CS throughout his or her school career, it is simply by chance. There are a number of organizations that have been aiming at improving CSE in primary and secondary school (K-12) education for many years. Most initiatives that aim at introducing CS in K-12 education in Switzerland are funded and conducted by associations, foundations or even companies. The largest and most renowned one is the *Hasler foundation*. However, most of these programs and initiatives are focused primarily on secondary schools, and some even target only talented students.

Activities organized on a more regular, usually yearly, basis include project weeks in selected schools and competitions like the *Informatik-Biber*⁴ or the *Swiss Olympiad in Informatics*,⁵ or

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¹ For details see <http://v-ef.lehrplan.ch/index.php>

² For details see <http://www.lehrplan21.ch/rechtliche-grundlagen>

³ For details see <http://v-ef.lehrplan.ch/index.php?code=b|10|0&la= yes>

⁴ For details see <http://informatik-biber.ch/>

⁵ For details see <https://soi.ch/>

Figure 1. Cantons that will introduce LP 21. Green: Cantons that decreed the introduction of LP 21. Dark grey: Cantons where the decision is pending. Light grey: Cantons and francophone parts of cantons where LP 21 is not applicable.

offer teacher training. Among the few exceptions to date is the project “Primalogo-Programmieren an Primarschulen”,⁶ which was funded by the *Hasler foundation* as part of their *Fit in Informatik*-initiative. According to the project’s website, it has exposed approximately 4’000 children and 100 teachers to programming with Logo⁷ and thereby successfully introduced Computational Thinking (CT) and CSE in the primary school level. [14]

Regarding CSE initiatives on the level of the Swiss state, the implementation of the new LP 21 promises to have the greatest scope and impact and is therefore of the greatest importance for the comprehensive introduction of CSE in Swiss primary schools. The actual implementation of LP 21 proves to be highly difficult, however. Switzerland, with a population of eight million and located in the center of Europe is unique in many ways that bring about both great opportunities and challenges. It is a federal republic consisting of 26 cantons⁸ and having four social national

languages: German, French, Italian and Romansh (native speakers of this language are extremely few, and they all learn to speak German). The direct democracy and the state’s highly federalist character are deeply rooted in the society and influence all aspects of life. All cantons’ education systems differ considerably from one another, especially regarding compulsory education, which includes kindergarten, primary, and lower secondary school (total duration of approx. 11 years). Regarding the implementation of LP 21, each canton decides individually, if, when and how exactly it will implement it. To date, 19 of the 21 German-speaking cantons have agreed to implement at least some form of the new curriculum (see Figure 1).

One of the cantons that has already agreed to introduce a version of LP 21 in their schools and to change their curricula in order to include the elements of the module “Medien und Informatik”, starting in the school year 2018/19, is the canton of Solothurn.⁹

⁶ For details see <http://primalogo.ch/>

⁷ For details see <http://primalogo.ch/programmieren-primarschulen>

⁸ The 26 cantons are the member states of the Swiss Confederation. Each canton has its own constitution, legislature, government and courts. They are sovereign to the extent that

their sovereignty is not limited by federal law. The cantons also retain all powers and competencies not delegated to the Confederation by the constitution. Most significantly, the cantons are responsible for healthcare, welfare, law enforcement and public education; they also retain the power of taxation.

⁹ For details see <https://www.so.ch/verwaltung/departement-fuer-bildung-und-kultur/volksschulamt/lehrplan-21/>

Conversely, in the two cantons of Aargau and Appenzell Innerrhoden the decision is still pending due to significant popular opposition against it.

While ICT topics such as Microsoft Office, which are currently taught in schools, are commonly seen as useful for a professional career, programming and other CS topics are often perceived as subjects that should only be taught at university. A related argument is that less than 30% of all students in Switzerland will pursue a tertiary education after school anyways [4], so why should something academic like CS be taught to everyone? When being informed about the role of CSE or specifically introductions to programming in schools, a common type of reaction encountered in teachers is “well, that’s definitely something interesting to foster gifted students.”

To summarize, in a federalist country like Switzerland it is difficult to achieve school reforms with a top-down approach, i.e. by introducing bills. Each canton is autonomous, and the final decision is often made by a popular vote. We need to consider the culture of the parents, students, and teachers. CS is commonly perceived as something academic or suitable for gifted students only.

1.2 Scalable Game Design in Switzerland

Scalable Game Design (SGD) Switzerland is located at the Institute of Primary Education at the school of education of the University of Applied Sciences and Arts Northwestern Switzerland (FHNW). This school of education, with approximately 3,000 students, is the institution responsible for certified teacher training in the four northwestern Swiss cantons of Aargau, Basel-Stadt, Basel-Land and Solothurn.

SGD Switzerland draws on the comprehensive research results and extensive experiences of the U.S. SGD project, which has successfully broadened computer science participation in the United States through engaging teachers and students in game and simulation design [1,11]. This research builds upon previous SGD work on engaging students in CSE with reference to cyberlearning [10] and CT. CT has a pivotal role in the SGD project. In its understanding and application of the concept of CT, the SGD project follows the both famous and widely acknowledged definition by Jeannette Wing who describes CT as the “cognitive processes involved in the formulation of a problem as well as in the representation of solutions, which can be carried out equally effectively by humans and machines” [16]. In line with Wing’s definition, the SGD project considers CT a combination of mathematical-analytical thinking with natural sciences, engineering and other disciplines. In short, CT is conceptualized as *thinking with the computer*. It is regarded and employed as a way of thinking that uses the computer as an instrument to support the human thought process, to visualize the consequences of this thought process, and to formulate a problem so that a computer-supported solution can be introduced.

The didactic approach of SGD is based on a theory entitled the Zones of Proximal Flow [2], which combines Vygotsky’s Zone of Proximal Development [15] with Csikszentmihályi’s theories on Flow [3]. The approach’s central aim is to keep students motivated through simulation and game design and thereby optimize their learning success. SGD’s comprehensive didactic approach with its focus on CT has resulted in the development, evaluation and providing of

- desktop and online programming environments that are specifically designed to teach and support CT and have been described as CT tools [13],

- tools for cyber learning,
- real time classroom management [1],
- implementation and evaluation of computational thinking [11],
- teacher professional development [11], and
- resources supporting low threshold/high ceiling curricula [2,9].

In the U.S., the SGD project has already helped over 20,000 students create their first games and simulations [11]. After over 20 years of research and teaching experience in the U.S., SGD extended its scope to Switzerland in 2014, when it was brought to the school of education at the FHNW. SGD Switzerland aims at adapting both contents and methods from the U.S. project to the specific affordances in Switzerland in order to expose Swiss teachers and students to STEM and CT through motivating game and simulation design activities. To this end, SGD Switzerland organizes the Swiss Computer Science Education Week [5,12], conducts teacher-training workshops and holds project workshops for students on different school levels. Supporting the implementation of the LP 21 in all its efforts and entertaining a long-term perspective that necessitates a sustainable strategy, SGD Switzerland also currently develops a curriculum for pre-service teacher training at the PH FHNW, which will be implemented in the form of two obligatory courses for all students of the Institute of Primary Education in 2017.

2. THE SOLOTHURN PROJECT

2.1 Concept and Aim

In preparation for the implementation of LP21, in the canton of Solothurn, and in order to find solutions about how to successfully accommodate the new curriculum needs, the CSE project “Scalable Game Design Solothurn” was developed. The project was designed and conducted by SGD Switzerland in collaboration with the office of compulsory education (Volksschulamt) of the canton of Solothurn. After learning about the SGD project and its multi-faceted, pedagogically thought-out curriculum of programming projects, the members of the Volksschulamt Solothurn decided that SGD would be an ideal method to introduce and teach CT on the primary school level. Choosing SGD’s research-based and practice-oriented approach that exposes students to CT through the two CT Tools AgentSheets and AgentCubes online, the project’s primary aim was to implement CSE in the primary schools of the canton of Solothurn.

2.2 Organization and Implementation

The project consisted of two parts: A continuing education training for the teachers followed by the introduction of the project and its techniques (i.e. teaching CT using SGD) by the teachers to their own students. The project’s implementation started in the spring of 2014 and lasted until the autumn of 2016. According to the original planning, two groups were created, resulting from two recruitment efforts: group 1, with five teachers, all having classes on the primary level and group 2, with two teachers, one with a class in secondary school and the other on the primary school level.

The continuing education training consisted of seven meetings with each group. In the course of the first three to four meetings, the participating teachers went through an intensive training course on CT. Apart from a general introduction to the concept of CT, this training included a project-oriented introduction to the software (i.e., the CT tools AgentSheets and AgentCubes online) and didactic strategies for teaching CT. The participants were provided with extensive teaching resources both online and in the

form of printouts. These included, among other things, detailed teacher guidelines for the introduction of coding activities in their classrooms, programming tutorials in step with actual teaching practice and easily adjustable according to individual students' skills, handouts for students and a set of debugging exercises. The training was intended to provide the participating teachers with sufficient knowledge, competences and self-confidence regarding the new contents and prepared them for teaching it to their students in their own classroom settings shortly afterwards. The teachers of group 1 used only AgentSheets both in their training and subsequently in their own classrooms with their students. In group 2, the teachers were additionally introduced to AgentCubes online, which they used as their tool to teach CT to their own classes.

The pedagogical concepts ensured that the majority of the students were highly motivated during classes, were able to work in teams as well as independently. The teaching methods introduced in the training were diverse and they were continuously revised in cooperation with the teachers and adapted to the local conditions. In parallel to their own training, the participating teachers began introducing the contents of the project to their classes. The focus of the subsequent meetings was more on exchanging experiences and receiving feedback from project leaders and the other participating teachers, regarding their own teaching activity.

2.3 Methods and Evaluation

In order to assess the success of the project and its suitability for a long-term inclusion of CSE in the educational curriculum of the primary school in the canton of Solothurn, a comprehensive evaluation was carried out. To this end, three questionnaires were developed and seven teachers, 133 students and 67 parents were surveyed. Of the students surveyed, 96 were from the primary school and 37 were from the secondary school. The quantitative questions were analyzed statistically, using the SPSS software for data analysis. The qualitative data were analyzed using a thematic analysis. Since the focus of the workshops differed not only amongst the teachers but also amongst the subsequent applications in the classroom, the data relating to workshop 1 (group 1) were analyzed in the presence of different trends separately from the data relating to workshop 2 (group 2). In addition, differences within group 2 between primary and secondary levels were observed. The latter differentiation was not relevant to group 1 since all students in that group were from the primary school level.

3. RESULTS

The project has proved to be successful in that, as expected, most students and especially the ones from the primary school level, showed great enthusiasm and motivation for programming. SGD is often associated with freedom in making your own decisions and working independently. The results are presented and discussed according to the three types of direct and indirect participants involved, i.e. teachers, students and parents.

3.1 Teachers

Most of the participating teachers and their students were, according to their own statements, highly motivated and profited very much from the continuing education, more specifically from the SGD teaching units. The analysis of the results paints a very positive picture of the project. After the training sessions, all seven surveyed teachers felt well to very well prepared for holding lessons in their own classes.

The participating teachers assessed the learning potential of SGD to be high (71.4 %) or even very high (28.6%). Also, all teachers thought that the lessons with SGD were received well (71.4%) or even very well (28.6%) by their students, which is in turn consistent with the statements of the students as well as of those of the parents. All seven teachers stated that game programming using AgentSheets / AgentCubes online promotes children's creativity and that they would recommend Scalable Game Design to their colleagues. The teachers also felt that the amount of time and effort required for the preparation of the actual lesson was low because of the quantity and quality of the teaching material provided. However, they would have liked to receive more practical examples of how to apply the material in special settings.

3.2 Students

The analysis of the results shows an equally positive picture among students. The vast majority of them (72.9%) said that they liked working with AgentSheets / AgentCubes online. Likewise, a large proportion (78.9%) of all students felt they had learned something new. These results vary according to age and school level and from teacher to teacher. For example, while only 56.8% of the secondary school students said they learned something new, 87.5% of the primary school students expressed that opinion. Looking only at the primary school students within group 2, the percentage of those saying they learned something new even goes up to 100% (see Figure 2).

Figure 2: Did you learn something new? Percentages of the students' answer according to school level and type of response (yes or no).

Asked to describe what it was that they had learned, almost all students gave answers that can be related to learning programming and CT. Many students gave statements like "I learned programming" (66 mentions), "I can give/write a command" (4 mentions) and "I learned that you really have to program everything and that it does not work if you make a mistake" (5 mentions). Other answers were more directly related to the kind of project they were programming, i.e. versions of the 1980s Arcade Frogger or Pacman games. Those students said things like "I learned how to make/build a game" (11 mentions) and "I learned how to make something appear/disappear" (6 mentions).

The results also show that cooperation between the students was encouraged. Not only did almost all teachers testify to this, but also the statements of the students. A quarter of all students stated that they often sought help from other students when they encountered a problem. When asked if other children were able to help them when they needed assistance with the programming, a huge majority said yes (in group 1: 78.7% of all students; in group 2: 95.2% of all primary school students and 73.7% of all

secondary school students). In a similar vein, most students expressed a high level of confidence in their ability to help other students in case they were asked for assistance. 73.3% of all students in group 1 confirmed that they were able to help others. The same is true for 71.4% of all primary school students and 73% of all secondary school students in group 2. Apart from proving a high level of co-operation between students during the programming classes, these answers also illustrate that students were very confident concerning the things they had only recently learned and are proof of the high learning potential of SGD.

The findings furthermore indicate that the students' motivation to continue working with AgentSheets/ AgentCubes online was generally rather high. This applies especially to the younger children who show the highest motivation. In order to determine the differences between the group mean values of the pupils' motivation for continuing working with AgentSheets/ AgentCubes online, we conducted a variance analysis with the dependent variable of motivation and the independent variable of teacher. The analysis showed a significant difference between the mean values. The post hoc tests (Scheffé) show that the class of teacher 1 in group 1 contains by far the most motivated students and significantly differs from all other teachers' classes. There are no significant differences between the other classes, however, partly because the motivation variance within the classes is relatively high (see Figure 3).

Figure 3. Motivation averages for continuing working with AgentSheets / AgentCubes online of the groups as defined by their teachers

When asked what they liked best about programming a game, the great majority of answers show that students appreciated the opportunity to freely use their imagination, be creative and work independently on their own projects/games. These results also coincide with the information given by the parents. The vast majority of parents of primary school students confirmed that their children were talking about SGD at home, saying that they had programmed a computer game (11 mentions) and had fun (13 mentions). This is an impressive argument for the special suitability of this project for primary schools.

3.3 Parents

The analysis of the data showed that parents have a very heterogeneous understanding of the term "Computer Science Education", expressing very different ideas about what their child had learned in the context of the project. Most parents assumed that their children learned general CS concepts and basic computer applications. 32% of the parents of students in the secondary level assessed the teaching of CS on that level as rather

not useful. This percentage is much higher than the one of the parents of students on the primary level, where only 11% from group 1 and 19% from group 2 made the same assessment. In that case more than 80% of the parents assessed CSE as useful to very useful and important for their children's future.

4. DISCUSSION

The analysis of the data clearly shows that CS taught with SGD is welcomed by teachers, students and parents on both primary and secondary levels. With regards to the continuing education for the teachers, the results indicate that teachers can easily learn to teach the subject of CS even if they do not have previous knowledge. Much depends upon the teacher's attitude and motivation as well as upon the provided educational material, didactic techniques and teaching tools. Even though the teachers who participated in the Solothurn project were enthusiastic for the most part, more research should focus on how we can make CS appealing to teachers so the latter can develop a more positive attitude. As for making the training more effective much attention should be given to the suggestions made and the needs expressed by the teachers who participated in the Solothurn training. For example making sure that in addition to theory the training provides more practical examples of how to apply the material in special settings. The more the content of the training is developed in cooperation with the teachers the more effective it will be.

Regarding the data from the students, even though all students expressed positive opinions, it is interesting that the primary level students were generally more motivated and more enthusiastic about the project. According to many teachers' comments, age can explain part of this differentiation because students after primary school level are generally more skeptical and less easily enthused by new things. However, still the fact remains: Primary level students are more likely to embark on CSE adventures. Introducing CSE on the secondary level might be too late. These are very important findings because they strongly suggest the necessity of introducing CT and CS as early as possible in a student's career, promising a both effective and sustainable interest in CT, CS and CS related fields. When children are familiarized with CSE already in their primary school years, they can be taught more advanced and more exciting CS subjects in secondary school, topics that are more in accordance with their interests and age. Following up on that, future research should be focusing on the further refinement of Computational Thinking tools that successfully capture the interests and affordances of secondary level students. When looking selectively at the data obtained only from the primary school students of both groups, it is striking that the students of teacher 1 in group 1 (left-most bar in figure 3) were by far the most motivated when asked if they wanted to continue working with AgentSheets/ AgentCubes online. We argue that this statistically significant variance can be explained by the specificities of the teacher and that the teacher's attitude towards the new subject plays a key role in raising (or lowering) the motivation levels of students.

Another factor that we think heavily influenced students' CSE experience was the kind of CT tool they used. A vast majority of the primary school students of group 2 expressed extremely positive opinions about their CSE learning experience. We argue that their exclusive usage of AgentCubes online was a significant factor towards their positive attitudes. More research is needed in order to investigate exactly what motivates students when using the various SGD tools as well as to understand the interactions between students and their teachers and their importance in the successful implementation of new educational subjects.

Finally, data analysis from the parents indicates that their lack of understanding of the concept of CT, may inhibit their children's interest and motivation and also may pose obstacles to the introduction of CSE into the Swiss school curriculum. More efforts should be made towards informing the parents about the benefits of CT. The fact that the majority of the parents of the primary level students showed a more positive attitude towards the importance of the subject might be an additional reason why the students were so positive towards it and vice versa. It also further supports our recommendation that CSE introduction should take place on the primary school level.

5. CONCLUSION

Even though CS is not an obligatory subject at any level in the Swiss education system yet, ICT knowledge is increasingly necessary not only for everyday activities but, more importantly, for building a successful future workforce. The Swiss education system is challenged to improve this situation. To this end, the aim of the CSE project "Scalable Game Design Solothurn" was to use a research-based and practice-oriented approach for introducing the field of CSE into selected classes using the two CT Tools AgentSheets and AgentCubes online. The project's main aim was to implement CT and CSE using SGD in the primary schools of the canton of Solothurn. The project succeeded in sufficiently training the teachers to teach CT to their students, who in turn learned basic concepts of CT. Analysis of the data shows that teaching CT through Scalable Game Design is not only feasible on the primary school level but also enjoyable. Our research also suggests that introducing CT concepts at the secondary level might be too late, recommending that instead, the key school level to a successful implementation of CSE to the Swiss education system is the primary school level. Improving the content of the continuing education training according to the teachers' requests and exploring further how to motivate more teachers, students, and parents and how to design age appropriate tools and teaching concepts are subjects to further research.

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