GeNIUS: Conditions for Successfully Teaching Computer Science Infused Natural Science Classes in Schools

Elena Yanakieva[1][0000−0002−2900−7252], Annette Bieniusa[1][0000−0002−1654−6118], Christoph Thyssen[1], Thomas Becka[3], Julia Albicker[2][0000−0002−1757−9050], Niklas Westermann[2], Barbara Pampel[2], and Johannes Huwer[2]

[1] University of Kaiserslautern-Landau, Kaiserslautern, Germany {elena.yanakieva,annette.bieniusa,christoph.thyssen}@rptu.de
[2] University of Konstanz, Konstanz, Germany {barbara.pampel, julia.albicker, johannes.huwer, niklas.westermann}@uni-konstanz.de
[3] Eduard-Spranger-Gymnasium, Landau, Germany

Abstract. Algorithmic and computational thinking are usually seen as solely computer science skills. However, we believe that algorithms are commonly utilized in other subjects, such as conducting experiments in natural science settings. This poster presents our work as part of the project "GeNIUS", which aims to develop scenarios for computer-science-infused natural science lessons in schools and derive the necessary conditions for successfully conducting such lessons. So far two such scenarios have been conceptualized and tested in German schools. Conditions such as reliable technical infrastructure, teachers' and students' prior experience with computer science basics have proven to be crucial for successful lessons.

Keywords: STEM · Computational Thinking · Algorithmic Thinking · Multi-disciplinary Teaching.

1 Introduction

Our ever-evolving digital society necessitates that schools adjust and provide future generations with the required skills to thrive. The Standing Conference of the Ministers of Education and Cultural Affairs in Germany (KMK)[4], responsible for education and schooling, has brought out a strategy called "Education in the Digital World" in 2016 [2], which aims to develop digital skills across schools. They have identified various computer science (CS) competencies anchored in established subjects that have not been sufficiently addressed. E.g., competence area "5. problem solving and acting", especially "5.5 recognizing and formulating algorithms" has been identified to be an integral part of the natural sciences, including biology, chemistry, and physics, as part of "designing and carrying

[4] https://www.kmk.org/kmk/information-in-english.html

J.-P. Pellet and G. Parriaux (Eds.): ISSEP 2023 Local Proceedings, pp. 203–206, 2023.
https://doi.org/10.5281/zenodo.8432002

out experiments", which is a competence requirement in their curriculum plan. Thus, CS-infused lessons, compatible with natural science lessons, are necessary.

We identified that the competencies proposed by KMK in its strategy fall under computational thinking (CT). CT describes the process of formulating a problem to executing a solution to the problem [6, 1]. Integration of CT and algorithmic concepts into lessons for conceptualizing problems and operationalizing their solutions show overlaps with scientific work [4, 3]:

- Understanding diagrams that describe or represent real-world problems;
- Planning tasks by systematically arranging the necessary processing steps;
- Using real data to examine critically and, if necessary, revise solutions;
- Break down complex processes into smaller parts;
- Create flow charts to represent different parts of a process.

With this poster, we aim to present our project GeNIUS, and its first results. GeNIUS aims to identify the necessary conditions to successfully offer scientific informatics education (SIE) as part of experimental natural science lessons while simultaneously providing lesson scenarios that can be easily adopted.

2 Project Description

As part of GeNIUS, lesson scenarios will be conceptualized in cooperation with teachers, according to the principle of participatory action, and conducted in schools, both such that enforce mandatory CS lessons and such that do not. The results will be evaluated concerning the conditions necessary to successfully integrate CT skills into the curriculum, specifically in natural science classes. These conditions may concern the conceptual parts but also the essential infrastructure.

Analogous to digitalized scientific research, algorithmic procedures for obtaining measurements in experiments can be individually adapted and actively experienced by students using simple programming environments and sensors. Through automation, time previously used for manual measurements can be used for other purposes. This makes it possible to implement didactic concepts that were once not feasible, which in turn requires didactic evaluation. Conditions for the success of SIE will be derived from evaluating such SIE scenarios. In addition, it will be investigated whether:

- students' subject-related competencies improve as a result of SIE,
- how students' and teachers' perceptions of respective subjects change and
- whether they grow subject-related interest and self-efficiency expectations.

The evaluation findings will be publicly available in the form of best practice examples. They will prepare science teachers in Germany for meaningful SIE in further training courses. The following section provides an insight into the design and evaluation of the first SIE scenarios.

3 First Results

So far, we have developed two lesson scenarios, with focus on students in German schools. These can be used as part of the curriculum of the combined subject "natural science" in grade 6 or, if the teacher sees fit, in any of the separate subjects - biology or physics in the later grades.

The first scenario focuses on insulation and energy efficiency in housing, and the second one tests how light affects plant growth. The students are expected to have already learned about the topics in the respective subject. The scenarios focus on providing a better understanding of the topic through hands-on experimentation. In both scenarios, the first phase is the experiment conceptualization. The teacher leads a discussion over the topic, and the students are encouraged to think about a possible experiment to answer the posed questions. A possible analogous experiment is discussed, which leads to the idea of potential automation of the process, as part of which an algorithm is formulated.

The next phase provides the CS basics of block-based programming and utilizing microcontrollers to acquire sensory data. The microcontroller used in both experiments is Calliope Mini [5], as it is the most commonly available in German schools. This phase can be omitted if the students are familiar with the basics.

In the next phases students work in groups of two. In the first scenario, each group receives a cardboard box, which serves the purpose of the house, and each group insulates their house with materials of their choice. Next, they implement the previously designed algorithm as a program for the Calliope Mini to measure the temperature. In the second experiment, two groups work on one plant. One group measures light and distance, while the second one measures moisture and temperature. Light serves as the control parameter; moisture and temperature remain constant. Three different settings are prepared: 100%, 50%, and 25% light transmission. The insulation experiment lasts approximately 30 minutes, while the plant growth one continues for seven days. In the end, a lesson is dedicated to discussing the observed results.

We conducted these scenarios in schools and outlined some critical conditions necessary for successful lessons.

Technical insfrastructure Many schools in Germany lack the necessary infrastructure to carry out long-term experiments such as the plant growth one. The school needs a reliable Internet connection to reliably save the data and display it in real-time for the students to observe the plant growth from anywhere. Furthermore, most schools we tested these scenarios in demand having accounts or certificates to establish an Internet connection. Calliope Mini supports only connection via simple SSID and password. Furthermore, some applications are disabled on the school devices, which can require specific workarounds.

Teachers' prior experience We are working with highly motivated teachers that acknowledge the necessity of digitalizing natural science lessons. However, motivation and high engagement are not enough when unforeseeable situations occur. Our experience shows that teachers who have prior experience with microcontrollers and feel more secure in teaching CS concepts can resolve technical difficulties among the students quicklier. Therefore, as part of GeNIUS, we are planning training sessions for teachers, in which CS skills will be developed, by using microcontrollers, focusing on Calliope Mini. These will help use them meaningfully as part of the school lessons.

Students' prior experience Students showed improved enthusiasm when using microcontrollers in lessons that are not commonly related to CS. We observed differences in handling technical difficulties between students already familiar with handling Calliope Mini and the ones who did not have prior experience. The latter was easily discouraged if something did not work out as intended - e.g., the connection did not succeed.

Despite the above-mentioned limitations, the tendency exists for students to feel more motivated to find out answers through digitally-guided hands-on experimentation. Furthermore, all teachers have stayed as highly motivated to conduct further scenarios with us in the upcoming school years. In addition, more teachers are showing interest to be part of GeNIUS.

4 Summary and Future Work

We briefly presented our project GeNIUS, which focuses on determining conditions for successfully integrating computer science concepts into natural science curriculum in schools.

In the future, we plan to enhance the two presented scenarios and conceptualize further ones for the separate subjects of biology, chemistry, and physics. We plan to evaluate both CS and subject-related competencies that the students acquire as part of these lessons. Also, further evaluation of the importance of the students' prior CS experience and preconceptions is intended.

Acknowledgments

This research was funded by the Federal Ministry of Education and Research (project “GeNIUS” grant number 16MF1011A and 16MF1011B).

References

1. Aho, A.V.: Computation and computational thinking. The computer journal **55**(7), 832–835 (2012)
2. DER KULTUSMINISTER, D.L., DEUTSCHLAND, I.D.B.: Strategie der kultusministerkonferenz ”bildung in der digitalen welt” (2017)
3. Drieling, K.: Der experimentelle Algorithmus: Das Beispiel Bodenversalzung. na (2006)
4. Eickelmann, B., Vahrenhold, J., Labusch, A.: Der Kompetenzbereich” Computational Thinking”. Erste Ergebnisse des Zusatzmoduls für Deutschland im internationalen Vergleich (2019)
5. Reese, K., Wolf, V.: Calliope mini. LOG IN: Vol. 38, No. 1 (2017)
6. Wing, J.M.: Computational thinking. Communications of the ACM **49**(3), 33–35 (2006)