Development and Testing of an Interactive Online Learning Environment with Focus on Algorithmic Tasks

Dario Naepfer[0000−0003−2092−9880]

ETH Zurich, Switzerland
dnaepfer@student.ethz.ch

Abstract. In this paper, we present the implementation of a new didactic concept in an interactive online learning environment and the extensive testing thereof. Its didactic goal is to support the development of algorithmic thinking by interactively solving small input instances of computing problems. The four approached competences are as follows:

1. To understand an abstract problem description and give proof of comprehension by classifying solution candidates into feasible and unfeasible solutions.
2. To find a solution for a given problem instance.
3. To find several different solutions for a given problem instance.
4. To apply criteria to evaluate and compare solution candidates and to search for optimal solutions.

The contribution of this paper is twofold: First, we design the didactic approach and realize a learning environment in accordance with the aforementioned competences. Second, we test the environment in schools under various circumstances and present results of live testing, survey sessions including written feedback as well as empirical test data derived from survey statistics. The empirical test covers user experience, intuitiveness of the learning environment, task difficulty, as well as satisfaction. This provides a genuine analysis of the application of the learning environment and allows drawing conclusions on the effectiveness of the applied didactic concept.

Keywords: online learning environment · elementary school · algorithmic thinking.

1 Introduction

Over the course of the past years, computer science has become significantly more important not only in the academic world, but also in modern society as a whole. Technological advance has affected the school system, changing the curriculum of elementary schools. In order to assimilate these changes, it is imperative that new technical and didactic ways of teaching students be developed. Logical and computational thinking, in particular, are now fundamental educational objectives. Consequently, a new concept supporting algorithmic thinking has been implemented in an interactive online learning environment [4] and was then exhaustively tested.

2 Didactic Goals

The didactic concept we present and apply aims to equip students to be able to encounter new problem formulations and learn how to solve them on their own. According to *Bloom's Taxonomy*, there are different levels of complexity depending on the cognitive dimensions of a task [3]. Here, four main competences are approached, which are based on the "Problem Solving and Algorithm Curriculum" that combines concepts such as constructivism and critical thinking with the hierarchy of *Bloom's revised taxonomy* [1]. The task levels of the learning environment are designed accordingly: Starting with simple classification tasks, the curriculum is designed such that the difficulty of the assignments improves gradually. Step by step, the students are taught the targeted algorithmic skills, similar to the classification informatics tasks of the *Bebras challenge on informatics* [2]. In this way, active learning and self-improvement are promoted. We will now link each task level with a didactic competence:

On the first level, the goal is to understand problem formulations and verify solution candidates. The student has to decide whether a given solution candidate is a feasible solution or not. In doing so, the student proves the competence of correct interpretation. A solution candidate is feasible if and only if it fully meets the task specifications.

The second level is concerned with finding solutions. At this competence level, the student is confronted with tasks for which a permissible solution must be found without any further help. The learning objective here is to find ways of dealing with a new challenge, and the student's creativity is required.

The third competence level approaches the competence to find multiple solutions that differ from each other. In contrast to the previous level, it is less useful to use mere brute-force search, and it is more effective to develop a strategy to solve the problem. Students can later learn to use decision trees to systematically list all solutions as a new competence.

The fourth and highest competence level involves finding optimal solutions. It requires the student to evaluate different solutions with respect to a given criterion. This enables the student to compare the solutions and select an optimal one. Given the target group, the variety of solutions must be small enough to enable the student to list all the different solutions, and to choose the best one.

3 Empirical Test in Schools

As a second step, the learning environment that implements the didactic concept was realized and then tested in various elementary schools. In total, over a hundred people participated in the test. Some representative statistics are shown below to illustrate the results. The data includes feedback from about 70 students aged between 8 and 12, equally distributed in terms of age, background, and academic performance. For simplicity's and brevity's sake, only overall results are presented.

First, the platform was evaluated in terms of understandability and intuitiveness. How long it took the participating students in average to understand an exercise is visualized in Figure 1. Over 90 percent of all students considered the tasks to be intuitive and easy to understand. Only a small percentile had difficulties and asked someone else for help. Further, how often the users did not understand tasks and then opened a tutorial with further explanations was measured. The result is visible in Figure 2. It provides insight into the approaches users choose to handle new tasks and indicates active learning. Also, the results yield information on the intuitiveness of each task. More than half of the students tested did not even look at a tutorial once, and less than 20 percent did it for more than one task.

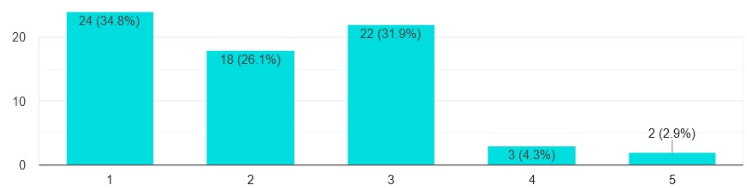

Fig. 1. Diagram representing the task understandability, linearly scaled from 1 to 5. 1 corresponds to ‘easy to understand’ and 5 to ‘hard to understand’.

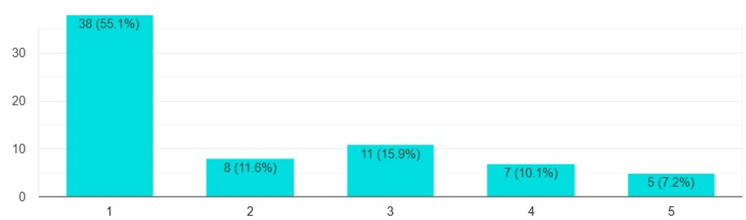

Fig. 2. Diagram representing the consultations of an additional tutorial, linearly scaled from 1 to 5. 1 corresponds to ‘not very often’ and 5 to ‘very often’.

Next, statistics on user satisfaction were gathered. The users were asked if they liked the exercises. Over 80 percent of the users indicated that they were pleased with the learning environment - see Figure 3. Only a small percentile did not like all the exercises. Additional feedback analysis has shown that challenges that were perceived to be either too easy or too hard resulted in a low fun factor.

Subsequently, the task difficulty was measured. Also, the time it took the students to solve single task instances was measured. Figure 4 gives an overview of the empirical data for this section. A small percentile of students was able to handle the tasks effortlessly, others were overwhelmed by the different task sets; and most students were seriously challenged. These results agree with regular academic performance statistics, which follow a normal distribution.

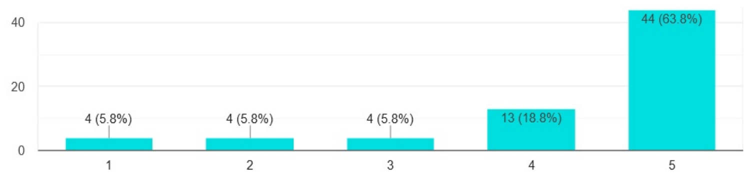

Fig. 3. Diagram representing the perceived fun factor, linearly scaled from 1 to 5. 1 corresponds to 'not so much fun' and 5 to 'much fun'.

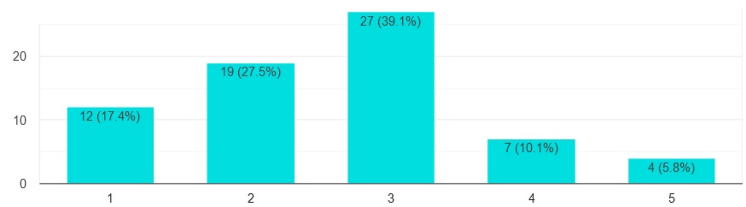

Fig. 4. Diagram representing the perceived task difficulty, linearly scaled from 1 to 5. 1 corresponds to 'easy' and 5 to 'hard'.

4 Conclusion and Discussions

The development of technical and didactic ways of teaching students is vital to ensure a sustainable education in the 21st century. Our contribution is to characterize an online learning environment that features diverse tasks that support the development of algorithmic thinking. The empirical test results indicate that the developed tasks are user-friendly, intuitive and interesting for the targeted student group. So far, the presented didactic concept has succeeded in the conducted tests. Everyone is invited to join the process by contributing and providing further feedback. Especially, new ideas for task concepts and test approaches are greatly appreciated.

References

1. Dagiene, V., Hromkovič, J., Lacher, R.: Designing informatics curriculum for K-12 education: From Concepts to Implementations. Informatics in Education (2021)
2. Dagiene, V., Hromkovič, J., Lacher, R.: A Two-Dimensional Classification Model for the Bebras Tasks on Informatics Based Simultaneously on Subfields and Competencies. Informatics in Schools. ISSEP 2020. (2020)
3. Anderson, L.W., Krathwohl, D.R.: A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. 2nd edn. Longman, New York (2001)
4. Learning Environment, https://itsmedario.github.io/. Last accessed 19 Jul 2021