Textbooks and Materials for Teaching Computer Science in Slovenia

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Abstract. In Slovenia, the RINOS working group has proposed changes to the curriculum and the introduction of computer science (CS) as a compulsory subject in accordance with the K12CS framework. An important step in the introduction of the subject is the development of new teaching materials and environments for teaching CS. Currently, most Slovenian materials for teaching CS are collected in the *Lusy library*. These include e-textbooks, materials for teaching CS, booklets of tasks and solutions, systems for various CS competitions, and platforms supporting practice of programming. Good teaching materials for CS should be relevant, interactive, easy to navigate, and promote active learning. Because CS education is a relatively new field, its didactics is almost constantly improving. Therefore, it is necessary to prepare teaching materials that can be easily modified, adapted and used for active learning. Various teaching materials with these properties can be found in the *Lusy library*. We conducted a qualitative survey among teachers of CS to assess the usefulness of existing materials and environments for teaching selected thematic units and to gain insight into teachers' needs. Our findings will provide the basis for developing useful practical teaching materials and activities for a future compulsory subject.

Keywords: Teaching materials · I-Textbooks · Interactive learning materials · Learning environments · Assessment platforms

1 Introduction

The first e-textbooks were digital copies of printed textbooks with easier navigation via hyperlinks and the ability to search the content [21]. Nowadays however,

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a good e-textbook differs significantly from a printed textbook. The digital format makes it easier to update the content, allows the use of multimedia and interactivity, and enables customisation to an individual or target a group of learners [15]. When creating e-textbooks, the advantages of their digital format must be properly exploited. The quality of an e-textbook is measured by how it contributes to the understanding of the topic presented. Technological advances have enabled new pedagogical approach. The ease of updating and customization is especially useful in the field of CS, because of the rapid development of CS curricula and its didactics. It is also useful that e-textbooks provide support for interactive elements, interactive tasks with instant feedback, and enable various analytics. Such e-textbooks are often referred to as i-textbooks [18].

Today, we can use various tools to develop i-textbooks and materials, such as free platforms openDSA [9] or Runestone, or payable platform zyBook [16]. These platforms not only support the creation of new materials, but also include examples of learning materials and a set of tasks with immediate feedback. Use of these platforms, makes it possible to use images, assess the knowledge through closed-ended questions, animate the implementation of the program code, write the code and check its correctness, etc. Studies have provided evidence that i-textbooks improve student performance and engagement compared to traditional textbooks [5,6]. Also a recent study by a research group at Aalto University found that the use of i-textbooks improved student motivation and learning compared to the use of static e-textbooks [19].

The development of textbooks and materials is influenced not only by the didactics of the subject, but also by the position of the subject in the curriculum. Currently, in Slovenia, CS is taught in basic education as an elective subject in grades 4–9. In the gymnasium it is taught as a compulsory subject in the first year, and as an elective matura subject in subsequent years. The current curricula are written openly giving teachers the freedom in teaching the subject and the selection of topics. On one hand, this freedom is beneficial, but on the other, it introduces problems. For example, the basic education curriculum lists many learning objectives without specifying which ones are fundamental and must be achieved by every student. As a result, teachers choose learning objectives according to their own preferences, which, unfortunately, most frequently only contain digital literacy.

In the elective CS courses in grades 4–6, the groups may consist of students of different ages, from different grades, and with different levels of knowledge, which makes the teaching even more challenging. In grades 7–9, the curriculum is still the same as in 2002 and is mainly based on digital literacy.

We are currently in the phase of introducing a new compulsory subject CS throughout the educational vertical. Namely in 2017, the Ministry of Education, Science and Sport of Slovenia set up an expert group RINOS. In Slovene RINOS stands for *Strokovna delovna skupina za analizo prisotnosti vsebin Računalništva in INformatike v programih Osnovnih in Srednjih šol ter za pripravo študije o možnih spremembah*, which translates to English as an *Expert working group for analysis of Computer Science topics presence in primary and secondary schools,*

and for a preparation of proposal of possible changes. In 2018 [3], the RINOS Expert Group made a proposal, that was also approved by the The Slovenian Academy of Sciences and Arts, to change the curricula by introduction of the compulsory subject CS into primary and secondary schools. Following the K12CS framework, the proposed curriculum covers the following topics: data and analysis, algorithms and programming, computer systems, networks and the Internet, and the impacts of computing [12]. However, shifting the focus from digital literacy to core CS concepts requires a change in teaching methods and the creation of appropriate instructional materials.

In the rest of the paper we introduce some textbooks and materials for teaching CS in Slovenia, which is followed by the presentation of survey results on the use of and need for textbooks and materials for learning and teaching CS. It was conducted among CS teachers in Slovenian primary and secondary schools. Finally, we summarise the findings from the literature and the research mentioned above.

2 Textbooks and Materials for Computer Science Teaching

In recent years, numerous e-materials and e-textbooks for CS education have also been created in Slovenia. Most of them can be found at the *Lusy library*[1] (Fig. 1).

2.1 Materials and Platforms

In this section we present some of the most popular and widely used online materials used by Slovenian teachers.

Vidra - CS Unplugged. The portal *Vidra* contains a collection of free learning materials for learning CS with games and puzzles, using cards, strings, crayons, and lots of movement. The Slovenian adaptation is based on the well-known CS Unplugged [2]. The materials provide CS teachers with interesting ideas and descriptions of activities. They can also be used in other subjects, especially mathematics, in clubs and as extracurricular activities. The materials cover topics such as binary numbers, graphs, sorting algorithms, and artificial intelligence [4].

Code.org. This is a website for learning CS fundamentals and includes online and hands-on activities. It teaches students computational thinking skills, problem solving, programming concepts, and digital citizenship. The developers have created learning paths that allow students to solve problems on their own. Substantial part of Code.org is translated into Slovene and is used by teachers mostly as additional material in class.

[1] https://lusy.fri.uni-lj.si/ucbenik/.

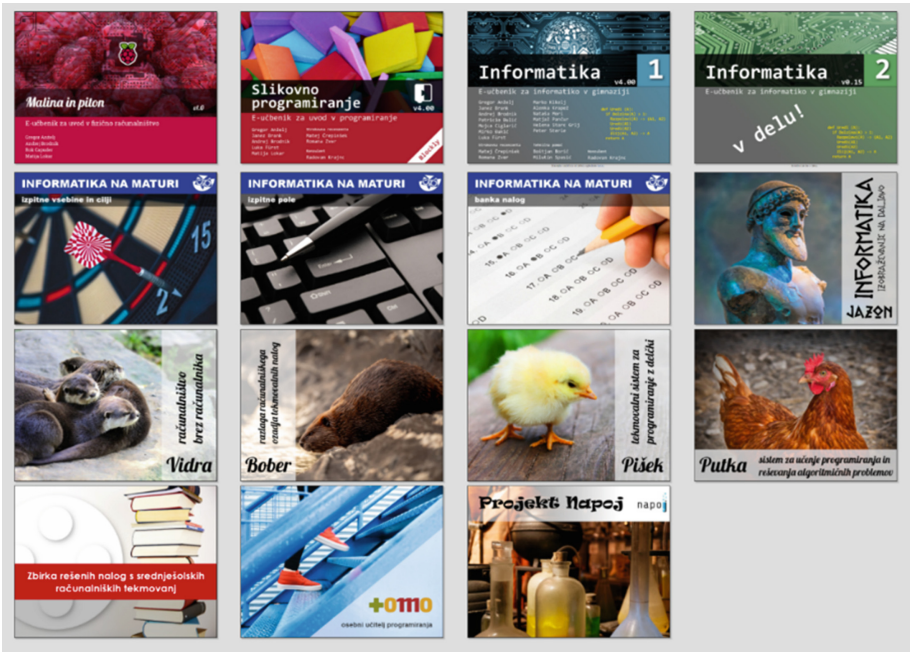

Fig. 1. *Lusy library*, central access point for i-textbooks and e-materials for CS.

Bober. The ACM Slovenia Bober Competition (from here on Bober) is a part of the International Challenge on Informatics and Computational Thinking Bebras. It is aimed at students from the 2nd grade of primary school to the end of secondary school. A very important result of this activity is the booklet with tasks and their solutions, published annually under the CC BY-SA license. It serves as a teaching material widely used to promote development of computational thinking and as a preparation for the competition. The booklet contains tasks and correct solutions with a detailed explanation of the correct solutions. For each task there is also a description of the CS background.

Pišek. The Pišek platform supports learning introductory block-based programming. It was created in 2018 based on the French system Algorea [10]. The portal contains a collection of tasks to be solved using the programming language Blockly and gives the user immediate feedback on the correctness of the solution. There are three main types of tasks in Pišek: tasks on the grid, tasks with turtle graphics, and "classic input/output" tasks. Tasks have different approaches to solutions: assembling a program, correcting a program, completing the program, and Parsons-type tasks. The platform is used on a national level for the ACM Slovenia Pišek competition, which annually wraps up with a booklet of tasks and their solutions.

Project Tomo. Project Tomo provides a rich library of tasks. When solving tasks, Tomo provides students with an immediate feedback on the correctness of the code. Teachers can set up their own "classrooms" with a selection of programming tasks for their students. They can use tasks from a library or create their own. Practical experience of high school teachers show that Tomo is particularly useful when teaching groups of students with heterogeneous knowledge [11,14]. Teachers pointed out that the system helps them prepare learning materials, monitor students' progress, and analyse their work. It facilitates teachers to individualise instruction and enable students to progress faster.

Putka. The set of platforms concludes Putka that is used predominantly for competitive programming on a national (ACM Slovenia RTK - national level Olympiad in informatics, ACM Slovenia UPM - national level of ICPC competition) and international level (CEOI, CERC). It also contains a rich collection of tasks that is accompanied with their solutions and explanations in *Zbirka rešenih nalog* (Booklet of solved tasks).

2.2 I-Textbooks

Due to changes in the curricula in 2013, it was necessary to write a new textbook for Informatics that replaced the old one, which was oriented very strongly towards computing literacy. Authors decided to write an interactive textbook that would be accessible online free of charge [17]. The i-textbook Informatics 1 covers four topics: programming and algorithms, systems, networks and distributed systems, and informatics and society [1]. It is well received by teachers, especially since it is constantly updated, mostly through teachers' input (e.g. errors discovered, suggestions). At the moment, the i-textbook Informatics 2 is also being developed, covering topics of information presentation, knowledge technology, and object-oriented programming. The authors plan to give teachers even greater opportunities to actively participate in the creation of the i-textbook, especially by providing opinions and evaluations of the content itself.

I-textbook is designed so that one can create different sequences of learning units and add own learning units as needed. The modularity and the possibility to adapt the i-textbook to one's own needs are considered a great advantage.

Since the i-textbook can be used also offline, it is designed as a series of interconnected static web pages. Interactivity is implemented using JavaScript, which allows for a single web page to be executed locally in a browser. In addition to the content, the authors also focused on the use of i-textbooks on different devices. This was mainly achieved by automatically adapting most of the content to the screen size.

On the other hand, when the i-textbook is used online, it provides a rich set of hyperlinks to other materials and platforms. For the former the inclusion of appropriate matura examination tasks with each learning unit is being implemented. Each learning unit is linked to the national SIO.si platform with class materials, and to the Tomo platform.

The chapter on programming and algorithms was reused in the i-textbooks *Slikovno programiranje* about block-based programming and *Malina in piton* on physical computing. The first uses Blockly instead of Python as the programming language and links to Pišek instead of Tomo. The second i-textbook uses the physical computing as a means to learn programming.

All of the available i-textbooks are released under Creative Commons license, more specifically they are released under CC BY-NC-SA 2.5 SI.

The usefulness of Informatics 1 i-textbook was evaluated with a survey of 61 CS teachers [17]. More than 90% of the teachers felt that the content was well explained. The interactive elements were also highly rated, especially the animations, the integrated Python interpreter, and the tasks with immediate feedback. Figure 2 shows the most frequent uses of the textbook.

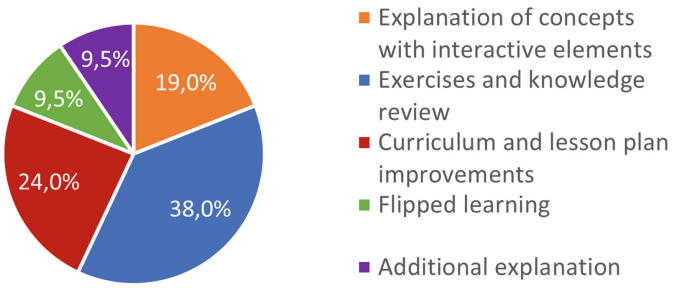

Fig. 2. Frequency of different uses of i-textbook in lessons.

3 Research on Teacher's Opinions on Existing E-Materials and I-Textbooks for CS

Through a survey of CS teachers, we aimed to assess the usefulness of existing materials and environments for teaching selected topics. The study was based on a combination of qualitative and quantitative research methods. As part of the survey, we were interested in what materials teachers use, how often they use them, and in which grades. We wanted to know what their needs were for materials on various topics: computer systems, data and analysis, algorithms and programming, networks and the Internet, and the effects of computing. We also investigated what features of e-materials are most important to teachers, what their experiences have been with using them, and what requirements they have for the materials.

3.1 Sample Description and Analysis of Responses

CS teachers were invited to complete the survey in early 2022. Responding 156 teachers were of different age groups and have been teaching CS and informatics subjects for different periods of time. All age groups were well represented,

with the majority of teachers (83%) having up to 25 years of teaching experience. The majority of teachers surveyed teach or taught various CS subjects at basic education. Computer club was run by 53% of the teachers surveyed. High school subject Informatics was taught by 29% of the teachers. Computer science subjects in vocational high school were taught by 16% of the respondents.

The sample of teachers surveyed seems to be very motivated to improve their teaching: 57% attend PD programs more than once per year and 28% attend PD at least once a year. 76% of respondents are mentors to students in the computational thinking competition Bober, 32% mentor students in the ACM Slovenia Pišek competition and 11% mentor students in the high school programming competition ACM Slovenia RTK. 19% of respondents are not mentors to students in CS competitions.

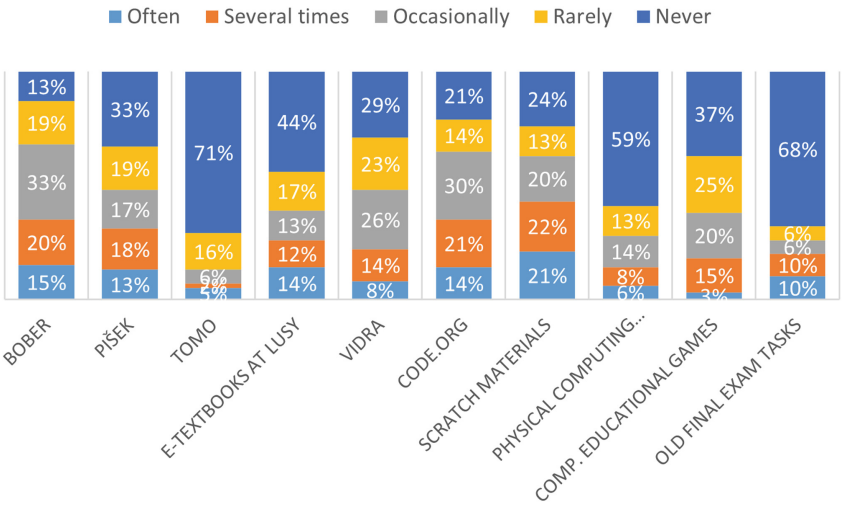

Fig. 3. Frequency of use of existing materials in lessons.

Teachers use a variety of materials in their teaching (Fig. 3), but most frequently they use tasks from the Bober competition. They most often use materials for learning Scratch, which is likely because basic education teachers commonly use Scratch in their classes, as it can be derived from their responses. Materials from Code.org, and Vidra are also popular. Teachers also use the Pišek portal, i-textbooks from the *Lusy library*, and educational computer games. Old matura tasks and the Project Tomo system are used by majority of high school teachers. Those teaching physical computing, use special learning materials for this purpose.

For practicing, teachers mostly use tasks from the Bober competition (62%), Scratch materials (61%), materials from Code.org (57%), and the Pišek portal (48%). Secondly, for frontal teaching they use Scratch materials (45%), materials from the portal Vidra (40%), i-textbooks from *Lusy library* (40%), tasks from

the Bober competition (34%), and the portal Pišek (32%). Finally, as additional teaching materials, teachers use tasks from the Bober competition (45%), Scratch materials (27%), materials from Code.org (27%), portal Pišek (25%), materials from the Vidra portal (24%), i-textbooks on *Lusy library* (24%), and educational computer games (23%).

We also surveyed teachers on their needs and current situation of instructional materials. The teachers' answers show that Algorithms and Data Structures is the most well covered topic and that there are enough high-quality materials for this topic (29% of respondents agree). The greatest need for new high-quality learning materials is on the topic Networks and the Internet. The biggest gap between the need and the current situation is in the topics of Computer Systems and Impact of Computing. There is also a need to create additional high-quality materials for Data Science.

CS teachers stress the importance of integrating interactive tasks into i-textbooks (88%) and aligning content with the curriculum (82%). Three quarters of respondents deem automatic verification of task solution correctness an important part of i-textbooks. 65% of respondents indicate that ease of navigation in the e-textbook and inclusion of multimedia elements are also important. Nearly half (45%) of respondents would like e-textbooks to be customizable, to have content added to them, or to have certain parts removed or changed.

The question about experiences with using existing e-textbooks and interactive materials was answered by 67 primary education teachers, 30 high school teachers, and 10 vocational high school teachers. The opinions of primary education teachers are divided: 23 of them had good experiences, 17 had mixed experiences, and 11 had bad experiences. As an example of a good resource, teachers highlighted the portal Pišek and the interactive tasks on Code.org.

A very important comment was the observation that a number of high-quality interactive materials have been produced through different projects in the past, but these are no longer maintained and are consequently outdated. They also point out that many learning materials are not adapted to the basic education level and are therefore unsuitable for students at this age. The problems are non-systematic escalation of the complexity of tasks, and for students in grades 4–6 the lack of learning materials in Slovene. Teachers noted that there are many high-quality teaching materials in foreign languages. Many of them translate the resources, but due to an uncoordinated approach, their efforts are unnecessarily multiplied.

Most high school teachers had good (14 teachers) or mixed (13 teachers) experiences with e-textbooks and interactive learning materials. Only one teacher expressed the opinion that the available materials were inadequate and that she has to create them herself. The most frequently used resource for high school teachers is the i-textbook Informatics 1. It is perceived by teachers as useful, professionally relevant and also interesting for students. They also emphasise the importance of interactive tasks with immediate feedback.

The teachers in the secondary CS schools had good experiences with the use of e-textbooks and interactive learning materials. Only one teacher had a

decidedly bad experience. As a disadvantage, they pointed out that e-textbooks are sometimes too in-depth for the level of knowledge they require from their students. The main positives they expressed are ease of use, and the interactive tasks that allow students to get real-time feedback.

Teachers of other secondary schools pointed out that there is a good i-textbook for high schools, but not for other secondary schools. A significant number of them use at least part of this i-textbook for their work. They miss a list of different learning materials to help them design their own learning materials for the students. They also pointed out the need for regular updates of i-textbooks and other learning materials.

Teachers pointed out the following reasons for integrating interactive learning materials into CS lessons:

- "Interactive materials are more attractive to students because they provide a sense of involvement."
- "E-textbooks are very welcome in classroom, because they allow the teacher to let students work at their own pace."
- "In high school, the e-textbook is excellent and students get the full support they need in the subject of informatics. The students themselves were very complimentary about the i-textbook in the surveys we conducted at the end of the school year."

At the same time, teachers emphasize the importance of direct contact between students and teachers and are not "afraid" that modern i-textbooks and resources will make the teacher's job obsolete. E-textbooks and interactive materials are useful as supporting material for learning new topics, consolidating knowledge, providing immediate feedback on solutions of various tasks, and formative knowledge assessment.

Teachers were also asked what they miss in existing e-textbooks and interactive teaching materials. Basic education teachers pointed out that many of the resources are not updated (10 teachers). Teachers would like to see a collection of materials (9 teachers) to assist them in teaching CS subjects in basic education. They also wish to have exemplary lessons and useful advice for teaching individual content areas (7 teachers). They would like to see high-quality interactive learning materials with tasks that are adapted to the knowledge and interests of basic education children (8 teachers) and allow for differentiation.

Among high school teachers, we see a slightly lower demand for new interactive materials, which might be related to the fact that the i-textbook Informatics 1 is available. However, teachers pointed out that not all learning objectives are covered (15 teachers). 9 teachers would like to see more tasks or collections of tasks, and would also like the tasks to allow for differentiation between students (3 teachers) and for the tasks to be more practical (2 teachers).

4 Conclusions and Plans

According to [8,15,20] the desired characteristics of a good e-textbook or e-material are:

- Online availability: the e-textbook/material should be available online, with the ability to download and use it without an internet connection.
- Flexibility: it must be flexible to meet the needs of individual teachers, students and groups of students.
- Cost-effectiveness: developing e-textbook is more expensive than developing a traditional textbook due to the additional features and technological requirements. However, considering the entire life cycle of the textbook, with all updates, corrections, and the possibility of using certain components in other e-textbooks and other teaching materials, the total cost should be comparable or even lower.
- Sustainability: the e-textbook/material must allow adaptation to technological changes.
- Interoperability: the e-textbook should be accessible in different learning environments and with different tools.
- Usefulness in different pedagogical situations: In addition to use in face-to-face teaching, laboratory exercises, group work, flipped learning, homework, it is important to use and adapt individual parts of several e-textbooks to create a customised version of the e-textbook.

The following recommendations are well considered when creating e-textbooks [7,8,13]:

- Content and format must be separate.
- The material that is part of the e-textbook must be modular, allowing content to be added and removed.
- It is desirable that the technologies used are based on open source code.
- E-textbooks and all their parts must be transferable to different learning environments (e.g., online classrooms, learning management systems).
- E-textbooks within a given school environment should have a simple and consistent user interface.

We can conclude that the e-textbooks and e-materials used by teachers and students learning and teaching CS in Slovenian schools, presented in this paper, take into account most of the features and recommendations mentioned above. To a lesser extent, these materials can be adapted to individual needs and context of use [13,15].

CS teachers emphasize the importance of integrating interactive tasks into e-textbooks and the alignment of the content of textbooks with the subject curriculum. They believe that e-textbooks and interactive tutorials help them teach the subject matter, consolidate knowledge, check students' knowledge, as well as provide immediate feedback. Teachers miss high-quality materials for teaching and learning the elective CS subjects in the second educational cycle and materials for data and analysis, and CS effects on society, especially on popular topics such as artificial intelligence, security, and cryptography. Teachers would like to get examples of lesson plans for individual topics and more materials in Slovenian. Teachers would also like to see more examples and exercises of varying complexity.

In the future, e-textbooks and interactive materials in Slovenian should be provided, covering all topics from the curricula and regularly updated in line with the research in Computer Science education.

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