Interactive Textbooks in School Informatics: A Case Study in Estonia

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Abstract. A move from printed to digital textbooks is often implemented on three different levels, while the highest level is interactive textbook that is able to check the learners' responses to learning tasks (incl. program code) and give personalised, automated feedback. Such interactive textbooks were developed in Estonia to support implementation of radically reformed national curriculum in informatics. This paper summarises a case study focusing on design, development and piloting of two online textbooks

Keywords: E-textbooks, Interactive learning resources, School informatics.

1 Introduction

Informatics is probably the first candidate among all school subjects when it comes to switching from printed to digital textbooks, as the students have to study this subject with the help of computers anyway. Although there exist a multitude of traditional (text-based) and innovative (interactive, gamified, project-based) online learning resources for teaching coding, the official informatics textbooks are still printed in many countries. The situation is different in Estonia, where there have been technically no printed textbooks available in informatics since 1996. It has to do with the tiny size of the country and, consequently, its textbook market, but also with the marginal status of informatics as a subject in Estonian schools. Estonian informatics teachers are used to rely on self-created learning materials and open educational resources they have found online. The situation has been changing in recent years, as a result of development of new curriculum for informatics. The ministry of Education and Research supported the development of online interactive textbooks for informatics that have been introduced in schools. The paper analyses the design, use and reception of these digital textbooks and proposes the further developments.

This study is guided by the following research questions:

- What are the pedagogical and technological design requirements for interactive textbooks in school informatics?

- How can we support creativity, collaboration and self-regulation of learners in informatics courses through changing the design of interactive textbooks?
- What are the shortcomings of piloted e-textbooks according to the students and teachers and how these can be addressed by design improvements?

2 Theoretical framework: key concepts and approaches

Informatics textbooks should provide students with theoretical basis as well as with more subject specific practical skills, such as general problem-solving skills, algorithm design, programming, robotics, creation of various multimedia content etc. In order to provide computer science students with subject specific e-textbooks numerous attempts was done.

2.1 Evolution of e-textbooks: historical retrospective

E-textbook or digital textbook is a new format for educational resources which emerged in the last quarter of the XX century, but the roots of this idea go further back in time. Inspired by Pressey's concept of teaching machines, Skinner (1954) proposed the idea of programmed instruction that led to designing adaptive, non-linear textbooks that were implemented both in printed and mechanical formats. Skinner (ibid.) criticized traditional, uniform and linear instruction in schools and suggested a new kind of textbooks that provided some branching options based on students' interaction with the content.

First mass-produced electronic textbooks appeared in US schools in the beginning of 1990s and were merely digital versions of printed textbooks (Schwarz et al, 1996). However, some researchers explored also the interactivity as a way to radically enhance the e-textbooks. For example, Fowler & Fowler (1993) used hypertext with the purpose to integrate concepts introduced in the classroom and text (the course lecture material, course syllabus), with the instructional design (a large set of designs and example programs) and programming environment (laboratory exercises, programming assignments). A year later Benfordet et al (1994) showed another example of adding interactivity to the e-textbooks by providing not only online access to the text of lectures and programming problems but also adding a tool to evaluate the solutions delivered by students and provide the student with informative, personalised feedback. An alternative concept of digital learning resources was introduced in 1994 by Wayne Hodgins (Hodgins, 2002), who suggested that the monolithic, linear textbooks should be replaced by small digital 'learning objects' that can be combined and re-used by learners and teachers according to their learning needs.

Since the turn of millennium, the speed of digital transformation of education has increased, resulting with new ideas how to improve digital textbooks. Jang (2014) described digital textbooks that include hypertext, multimedia and interactive functions that enable learners to learn according to their aptitudes, abilities, and levels. Dwyer & Davidson (2014) suggested that e-textbooks should include (on top of video and hyperlinks) also built-in dictionaries and pronunciation guides, bookmarking, highlighting

and underlining capabilities, full-text searching, and the linking of the multimedia objects. Gu et al (2015) conceptualised e-textbook as a digital learning platform that combines features of e-learning and e-publishing technologies, and serves as dynamic and interactive reading material, and as an interface for learning activities among learners and the learning communities. During the first decade of 21st century, many academic publishers introduced the digital learning resources in a form of standardised SCORM content packages that can be imported to a Learning Management System (LMS, e.g. Moodle or Blackboard) and used interactively instead of traditional textbooks.

Lokar (2015) found that even today, publishers are trying to stress similarities of traditional and digital textbooks: "*An eTextbook is the complete contents of a printed textbook, delivered in electronic form over the Internet. An eTextbook has the same content as a printed textbook, the same chapter divisions, and the same page numbering*". On the other hand, the e-textbook researchers and innovators are more interested in moving away from the traditional concept. Pesek et al (2014) describe three levels of e-textbook evolution:

1) **digitalized textbooks**: The content is the same as in the print version. Their only elements are text and pictures. The only added value is the option to add comments and notes more easily;

2) **rich textbooks** incorporate some form of interactivity. They add video and sound elements, some forms of interactive questions are present;

3) **interactive textbooks** have all the elements of digitalized and rich textbooks but also the content adapted to human to computer interaction, interactive elements (dynamic interactive constructions), interactive progress check (instant feedback), the possibility to save answers, success rate analysis.

This brief historical overview shows that there have been at least three alternative scenarios of development of digital learning resources:

1. enhancing the original concept of textbooks by using new digital publishing formats (PDF, ePub, HTML5) and adding some new features enabled by new digital technologies, such as non-linearity (hypertext), multimedia, interactive exercises with automated feedback
2. re-defining e-textbooks as standardised, interactive (yet mostly linear) content packages that can be integrated into various institutional e-learning platforms
3. replacing the idea of uniform, pre-designed textbooks with repositories of reusable, atomic learning objects that can be combined into a meaningful whole by learner or teacher him/herself, sometimes with the help of an intelligent recommender system.

In this paper, we follow mostly the first scenario (borrowing some ideas from the second and third scenario), while aiming at the third level of e-textbook evolution as defined by Pesek et al (see above) - interactive textbooks.

What would be the next stage in the evolution of e-textbooks? Väljataga et al (2015) claim that the bulk of digital learning material and e-textbook solutions currently available are still not supporting the more ambitious pedagogical innovation aspiring more learner-centered, self-directed, creative and collaborative learning. They propose (ibid.)

a taxonomy of distributed co-authorship levels that can be used for comparing the digital textbooks in future. The ambition of interactive textbooks for school informatics in Estonia has been clearly set to higher levels in CoA taxonomy.

2.2 Defining the e-textbook

The easiest way would be to define e-textbook as e-book that has been designed for learning purposes in accordance with curriculum standards. However, as we demonstrated in the historical overview above, an e-textbook does not have to be (and often is not) an e-book. Variety of e-textbook definitions can be found in literature, most of these focus on the digital format of educational content that includes not only text, but also hypertext and bookmarks (Fowler and Fowler, 1993), multimedia (Knight, 2015; Jang, 2014; Dwyer & Davidson 2014), feedback and assessment (Benfordet et al 1994), animations and videos (Regueira and Rodriguez, 2015). Railean (2015) gives a comprehensive definition of digital textbook: *'Digital textbook is a mix of workbook, reference book, exercise book, case book and manual of instruction based on static hypertext or multimodal text, which meet curriculum standards (pedagogic resources) or/and is an alternative learning tool, located in a digital library accessed through a personal computer or mobile digital device connected to Internet and directed from an educational platform*'.

Lokar (2015) suggests six key features of a good e-textbook:

– **Accessible**: an e-textbook should be available online and there should be the possibility of transferring it to other locations.

– **Adaptable**: an e-textbook should be adaptable to the needs of individual teachers, learners and groups of learners.

– **Cost effective**: an e-textbook should increase the efficiency and productivity by cutting the time and money spent on the whole lifecycle of a textbook, including future revisions, adaptations….

– **Durable**: an e-textbook should be adaptable to the changes in technology without costly redesign and re-encoding.

– **Interoperable**: an e-textbook should have the option of being used in different learning environments and with different tools.

– **Reusable**: an e-textbook should have the option of its parts being used in different contexts.

Choi et al (2018) propose five functional layers for development of next-generation e-textbooks that support constructivist learning:

1. *Core functions* – existing features of e-books form the core functions for e-textbook to replace printed textbook in learning. These functions improve the learning efficiency but do not make substantial functional change in learning process and, thus, would be the first step in deploying e-books to substitute printed text.
2. *Internet connection* – the ability to connect to the local area network and the Internet. Internet connection not only empowers learners to acquire learning resources anytime anywhere but also allows designing enhanced features to augment the learning with e-books. Nevertheless, adding internet connection to e-textbooks can only enhance the learning experience but do not revamp the learning process.

3. *Sharing and collaboration* – enable sharing and collaborating with other learners to facilitate collaborative learning. Collaborative learning modifies how knowledge can be created and acquired from the e-textbooks and, therefore, is a step towards transforming e-textbooks from a self-directed learning environment to formal learning platform.
4. *Personalized learning* – the capability to provide various types of learners with tailor-made instructions that fit their learning needs. Personalized learning further modifies the learning content delivery method of e-books and paths way for implementing new teaching pedagogy with e-textbooks.
5. *Intelligent tutor* – the use of state-of-the-art intelligent methods to gradually understand the learners by building student-centric models. Intelligent tutor completely redefines the e-textbook from a pure learning tool to a teaching and learning platform

While designing the interactive textbooks for Estonian school informatics, the features suggested by Lokar and Choi et al were used as design requirements.

3 The context: informatics curriculum reform in Estonia

This case study took place in a unique context defined by ongoing curriculum reform that has radically redefined the goals, content and delivery modes of Estonian school informatics. Current national curriculum (Riigi Teataja, 2014) originates from 2014 and it includes an elective subject 'Informatics' that recommends to schools the following contents to be taught as a separate subject (one 45-min lesson per week):

- Grade 5 or 6 (age 11-12): 'Learning with Computer' includes topics such as word processing, file management, internet search, analysing and visualising data, making presentations
- Grade 8 or 9: 'Information Society Technologies' includes topics such as online information systems and document management, eGovernance services, creating online Personal Learning Environment, participating in online community of practice, digital content creation.

High school (grade levels 10-12) curriculum does not mention the subject of informatics, but Science strand includes five elective courses with IT component (35 hours each):

- Using Computer for Inquiry
- Basics of Programming and Software Development
- Robotics and Mechatronics
- Geoinformatics
- 3D Modelling

However, schools in Estonia are free to decide which elective subjects to include in the school curriculum and how to teach these. Recent study (Praxis, 2017) showed that Informatics was offered as a separate subject only in 55 per cent of basic schools and 76 per cent of upper-secondary schools (grade 10-12). The rest of the schools have

integrated some ICT-related topics into other subjects to improve digital literacy of students. Coding is taught only in 2 per cent of basic schools and 23 per cent of upper-secondary schools that offer Informatics as a separate subject. This is in sharp contrast with articles published in the international media (e.g. Forbes, BBC) that claim that coding is taught as a compulsory subject in all Estonian schools. One of the main reasons why coding is not being taught in Estonian schools is the lack of qualified teachers and textbooks. Teacher education is offered only in University of Tartu and Tallinn University, both have started preparing informatics teachers since 1990. However, within last 10 years there have been only a few applicants every year to the MEd programme 'Teacher of Informatics' in Tallinn University, which caused shutting down the programme in 2015. University of Tartu continued offering it only as a minor specialisation module for mathematics/science teaching majors, but the enrolment number were dropping there as well. There are two reasons for the lack of interest: (1) as there are only few informatics lessons in every school, it does not provide a full teaching position in majority of schools, (2) majority of university students who are interested in computer science prefers to teaching a career in IT industry, where salaries are 2-4 times higher than teachers' salary. There only textbooks of informatics are available for primary school (Grades 1-6) and for five elective courses in upper-secondary schools. There are no specific software tools or online platform dedicated to teaching coding in Estonian language. Schools that teach coding tend to use the international platforms such as Code.org. There are some achievements in informatics education in Estonia, the most important one being the Estonian Informatics Olympiad (EIO) that is organised annually by Tartu Science School since 1990-ies. Estonian students (most of whom are self-taught or trained through non-formal education sector, e.g. coding clubs and EIO coaching team) participate every year in international competitions such as Informatics Olympiad and Bebras. There are also some success stories that belong to the non-formal IT-education:

- ProgeTiiger: in-service teacher training programme on teaching playful coding and robotics in grades 1 4 (by HITSA Foundation),
- SmartLab (NutiLabor): network of 170 coding clubs funded by Look@World Foundation
- Robotics competitions Robootika and First Lego League have massive attendance
- Cyber security initiatives in education: Safer Internet Day, Küberpähkel competition
- Privately-funded ICT projects in schools: Samsung Digital Turn, Samsung DigiPass, Eesti 2.0, Codesters Club etc.

Success factors for strong non-formal coding education in Estonia are: interested kids and parents, engagement of professionals from IT sector as trainers, availability of public-private funding and partnerships, and collaboration between universities, schools, companies and educational agencies. The main challenges of informatics education in Estonia have been increasing since the turn of the century: lack of qualified teachers, lack of textbooks and decrease in the willingness of schools to offer this subject to their students. Currently the coding skills of Estonian students are assessed only in the non-formal education sector (Informatics Olympiad, Bebras, First Lego League, Robootika). The things a little better with national level assessment of digital competences.

In 2017 and 2018, the joint research group of University of Tartu and Tallinn University conducted an online pilot test of digital competence in grades 9 and 12 by the request of the Ministry of Education and Research. The test is based on European digital competence framework DigComp and includes only 2 tasks related to simple coding skills. According to current plans, this test will be taken every spring by a random sample of 20 per cent of all students in grades 9 and 12 in upcoming years.

The expert group on informatics curriculum reform was formed at the HITSA foundation in 2017 and it defined the following design principles for new informatics curriculum for high schools:

- the main focus is on real-life software (or software+hardware) prototyping project
- the project can be defended as an inquiry project, as every high school graduate has to conduct a 'mini thesis'
- students themselves will select the topic and team mates for the project, appoint the team leader
- the project is collaborative, 4-6 team members have different roles (programmers, designer, tester, analyst, project manager)
- prior to the project, each student should take 1-2 courses to prepare for his/her role in the team
- curriculum should aim at balancing computational and design thinking
- curriculum and learning resources should be designed for flipped classroom approach
- teacher should be involved (both in elective courses and in the project) as a coach and if possible, supported by a mentor from IT industry

As a result of iterative and participatory design process conducted by HITSA expert group, the new informatics curriculum for high schools (GINF) was proposed in 2018. It consists of a collaborative software project in Grade 11 that is preceded by five role-based elective courses in Grade 10:

- Introduction to programming
- Basics of software engineering
- User-centered design and prototyping
- Software analysis and testing
- Digital services

Participation in the software development project requires that each participant has successfully passed 1-2 elective courses a year before, in accordance with their future role in the project team (developer, analyst, tester, designer or project manager) (HITSA, 2017). Due to the lack of qualified informatics teachers in Estonian schools, the elective courses and their online learning environment is designed to support self-directed and collaborative learning so it could be delivered also in these schools that do not have any informatics teachers. The online learning environment designed for GINF consists of the following components (HITSAa, 2017):

- Interactive textbook built on Wordpress with Pressbooks plugin and H5P templates for interactive self-tests

- Moodle with VPL (Virtual Programming Lab) plugin for conducting and assessing coding exercises
- Trello, Github, Slack and GSuite for teamwork.

To ensure implementation of GINF curriculum also in those schools that don't have a qualified informatics teacher, the textbooks had to support Flipped Classroom approach. Thus, the textbook should be designed to guide learners through learning materials, support the self-directed learning process by providing instant personalized feedback on completed tasks etc., while leaving to teacher a role of coach or facilitator who guides students through collaborative problem-solving process. At the moment GINF textbooks include but a few elements of learning analytics support but there is missing a path for using collected data for instant improvements and guidance, also a bridge that connects collected data and predicts student learning outcomes and behaviour in specific cases: completion of different tasks, reading additional information etc. In the future, the platform should enhance the support to innovative learning approaches such as personalised and collaborative learning or peer learning. Learning analytics and learner modeling should provide an overview of each and every student individual contribution to common work to ensure that learning outcomes listed in curriculum was obtained by all students.

This paper focuses on piloting the two textbooks designed by Tallinn University for elective courses 'User-centered Design and Prototyping' and 'Software analysis and testing'. Both textbooks were designed to support Flipped Classroom approach with duration of 8 or 16 weeks, depending on intensity of studies. This is why each textbook contains 8 chapters, each chapter containing text, images, videos, examples, interactive exercises made with H5P and 1-2 collaborative tasks for face-to-face workshop sessions. The Table of Contents for both textbooks are presented below:

- User-Centered Design and Prototyping (web.htk.tlu.ee/digitaru/disain/):
  - Design process and related key concepts
  - Mapping the needs of the target group
  - Personas and scenarios
  - Conceptual model
  - LoFi prototype of the User Interface
  - Interactive prototype of the User Interface
  - User experience evaluation
  - Pitching your prototype
- Software Analysis and Testing (web.htk.tlu.ee/digitaru/testimine/):
  - Software quality
  - Who is the analyst?
  - Software requirements
  - Who is the tester?
  - Basics of software testing
  - Software testing process
  - Presenting the results of testing

Both textbooks were piloted in 6 schools in 2019 with more than 200 students, the results and feedback are analysed below.

4 Research design and methods

Research design will follow mixed method case study approach (Yin, 2018). According to Creswell & Plano Clarke (2018), *'a mixed methods case study design is a type of mixed methods study in which the quantitative and qualitative data collection, results, and integration are used to provide in-depth evidence for a case(s) or develop cases for comparative analysis*' (Creswell & Plano Clarke, 2017). This approach was chosen in order to raise credibility of inferences from survey result and interviews conducted within the present study and provide scientific evidence regarding effectiveness of school informatics e-textbook design solutions.

According to (Zainal, 2007), case study explores and investigates a contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships. The case (pilot study) acts as a tool to explore effectiveness and needs of further development of two informatics e-textbooks ('User centered design and prototyping' and 'Software analysis and testing') that were composed by Tallinn University researchers for a new upper secondary school informatics curriculum. According to Yin (2018) case studies can be divided to three types: (a)explanatory, (b)descriptive and (c)exploratory. In our case, based on research questions stated above we will follow the path of explanatory case study.

By choosing the mixed method case study research design, we aimed to improve understanding the experiences, concerns and improvement ideas of students and teachers related to piloting the e-textbooks.

In order to ensure that different dimensions of informatics e-textbooks are addressed, we used methodological and data triangulation techniques. As methodological triangulation in present study we used literature review, post-pilot online survey of students and interviews with teachers.

5 Results

All five new GINF textbooks were offered for piloting to Estonian high schools, ten schools enlisted for this pilot. Out of these ten schools, six agreed to pilot the course ' User-Centered Design and Prototyping' and only two schools managed to find students for 'Software Analysis and Testing' course. These six pilot schools included one vocational school, one private full cycle school (grades 1 to 12), two large state high schools and two mid-size municipal high schools. Two schools were located in the capital city Tallinn, two in Pärnu, one in Tartu and one in Jõhvi. The post-pilot online survey questionnaire was responded by 41 students, which is slightly more than a half of the students who enrolled to the pilot course. The survey was conducted right after the end of the pilot course in June, while the collaborative software project (where the skills learned during the pilot course were put into practical use) took place in the beginning of the next school year, from September to December.

First, we wanted to map the wider context regarding everyday use of online information systems and learning resources by the students, as it could affect the learners' attitudes towards using e-textbooks in general. The significant majority of respondents (32 out of 41) reported daily use of school information system and 30 confirmed their daily use of online information seeking for study purposes. However, less than half of the respondents have been using regularly computers for accessing any kind of digital learning resources, tests, note-taking and quizzes. Only six students reported their engagement in coding and web design activities on weekly basis. 14 respondents have studied informatics in basic school as a compulsory subject, 13 did not have any previous experience with informatics in school or outside, 8 had informal or non-formal learning experiences related to IT (coding, robotics, 3D modelling, Web design). As these two pilot courses did not have any prerequisites regarding previous informatics knowledge and skills, the final sample for our survey matched the expected situation in all Estonian schools in general.

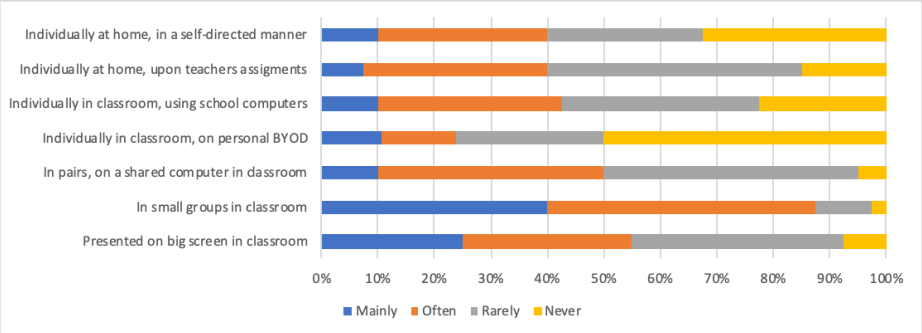

Fig. 1. The distribution of students' responses regarding the use of e-textbook.

The Figure 1 above illustrates the students' responses to the question: ' *How the use of the e-textbook was arranged in your school during piloting*?'. We expected the first two

options (*Individually at home*) would dominate, but it did not happen. The most common ways of reading the e-textbook were on the big screen or in small groups in classroom. Surprisingly large share of respondents was using the e-textbook in pairs on a shared computer, probably due to insufficient number of computers in school lab.

The Figure 2 below summarises the students' attitudes regarding the quality, difficulty, organisation and ease of use of the piloted e-textbooks. The highest level of satisfaction was related with interactive exercises, ease of use, support to independent studying, support to knowledge retention and transfer. The respondents were less satisfied with ease of getting started with this e-textbook, user-friendliness and support to flexible organisation of informatics studies. While the e-textbooks were specifically designed to support Flipped Classroom approach, it is understandable that some students did not cope so well with sudden expectance of independent, self-directed studying in the domain that they had no previous experience, which is supposedly quite different from the rest of their high school studies.

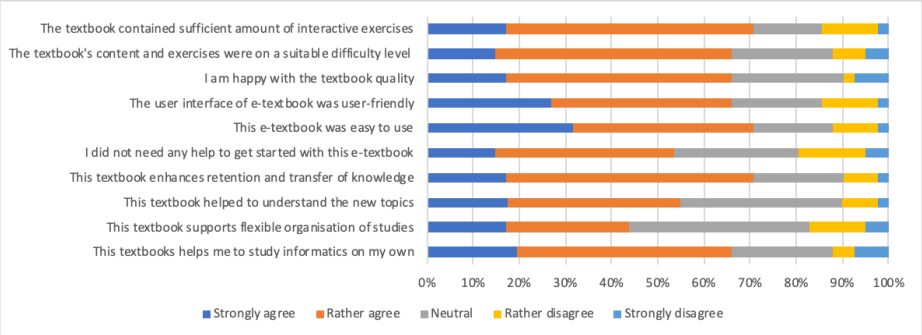

Fig. 2. Students' satisfaction with e-textbooks.

We also asked the students to estimate the further need and potential uptake of these e-textbooks in the future, both by themselves individually as well as by their school (Fig.3). 75% of respondents suggested that this elective course should be offered to the students in their school also in the future. Less than half of students thought they might revisit this textbook in future. Now we know that those students who took part also in the follow-up collaborative software development project a few months later, had to revisit and use actively both e-textbooks, indeed. It is encouraging that more than a half of the respondents think that there will be sufficient number of students in their school who would be interested to take this course in the future.

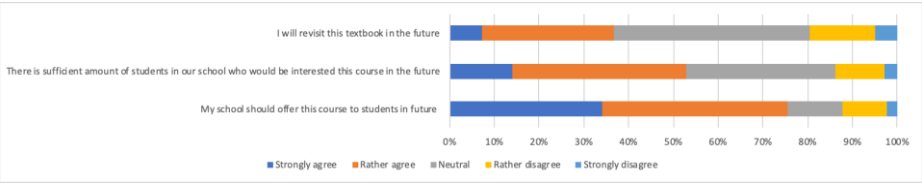

Fig. 3. The potential future use of piloted e-textbooks.

We asked students to give free-form feedback about most boring/useless and most interesting/useful topics covered by these two textbooks. Surprisingly, the most boring chapter was building an interactive prototype (mentioned by 5 students), while most interesting ones were the chapters about designing personas and pitching the prototype (mentioned by 4 students). As it happens, there were two respondents who had exactly opposite opinions. The reason for disliking the chapter about building an interactive prototype was caused by insufficient support and examples on using Marvel app, but also by the fact that Marvel app had frequent technical problems. Some respondents were critical about mistakes in the text (the piloted version have not been thoroughly edited). Flipped Classroom approach that was applied in theses pilot course found equal number of proponents and opponents amount students, the former appreciated an unusual way of studying, while latter would have preferred traditional lectures to independent work with the e-textbook.

The feedback from the teachers who participated in the pilot was collected by online questionnaire and group interview. The data collected from teachers confirmed the results of students' survey. The main challenges were related with Flipped Classroom approach that was not suitable to students that did not have independent learning habits. However, teachers confirmed that majority of students appreciated more self-directed form of learning in the pilot courses (with the exception of the private school where majority of students preferred traditional delivery of the course). Teachers also confirmed that the topics of writing the personas and pitching the prototype were the best ones in the textbook. An interesting comment was made by one teacher regarding the scenario task - she said that her students did not believe this task could be "so easy and fun" and were suspiciously looking for "catch". The teachers also said there should be more real-life examples in the textbook, but the examples should be drawn from the everyday context of students themselves.

6 Discussion and conclusions

The new e-textbooks for an experimental high school informatics curriculum were successfully piloted, the feedback from students and teachers was generally very positive and resulted with a number of suggestions how to improve the structure, design, visuals and text of the e-textbooks. These suggestions have already been taken into account when preparing the new versions of both e-textbooks that will be publicly launched in the beginning of the next school year. As these textbooks are designed to support independent studying and Flipped Classroom approach, it would be easy to use these also in case the schools will not open in September and have to teach fully online.

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