PARTICIPATORY DESIGN APPROACH TO TEACHING AND LEARNING OF SCHOOL MATHEMATICS

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Abstract

The thesis explores the possibilities of involving users – students and teachers – into the design process for an interactive textbook for assisting the teaching and learning of mathematics at a secondary school level. Involvement of students and teachers is executed with participatory design methodology for the purpose of infrastructuring between different actors – developers, designers, students and teachers, in order to suggest and emphasize novel, in terms of the market, ways for ideating, creating and evaluating concepts in the field of digital learning. The design process is executed with the aim of producing a re-design proposal for an existing interactive textbook – namely Exponent 1b by Gleerups Utbildning AB - a renowned Swedish publisher of learning materials. The proposal is part of the ideation phase of Gleerups’ project and the design process is addressed accordingly.

The initial sections introduce a theoretical framework for looking at interactive learning environments and present examples of such environments and their functionalities. Significant focus is dedicated to the preliminary analysis of the current state of Exponent 1b and the follow-up participatory analysis and re-design process. The author’s proposals for improvements in the core functionalities and the interactions are based on the initial research of the theoretical framework, presented examples of integrated learning environments examples and services, and predominantly on the outcomes from the participatory analysis and design process. At the end of the thesis the author summarizes the outcomes concerning involvement of students, teachers, designers and developers, and inclusion of digital tools to facilitate learning and variety in teaching.
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1. Introduction

Digital technologies are developing and conquering new ground every day. Like other technologies before them, they are transforming social and economical relations as well as public and private life (Buckingham 2008). They are ubiquitous – in professional life, in academia and in peer-to-peer activities for young people (Metzeger and Flanagin 2008). Nowadays the idea of digital “natives” and digital “immigrants” is discussed to encompass the difference in people who have grown up with the digital technology and those who have met with it later in life (Prensky 2006; Buckingham 2008). Young people and their interactions with technology are changing perceptions about communication, collaboration, innovation and participation and in that process are also changing our world (Tapscott 2008). One field where information and communication technology has an important role is education (Jupri et al. 2015). Access to specific information is now not further than one-click away.

1.1 Problem Domain

Instruction through digital means is an area that has been developed largely for the past couple of decades (Gee 2010). Digital media and learning is an emerging field of its own – one that deals with ways that the digital tools could help learning gains but also how the changing culture of media, production and participation enhances learning and from that perspective also transforms the world (Gee 2010).

The technologies have an intricate relationship with teaching – emerging technologies challenge educators to make use of them in the classroom but on the other hand use of the technologies by teachers has a direct impact on said technologies’ further development (Klopfer et al. in Them 2009).

Traditional textbooks are still undeniably present in every school but publishers have acknowledged the importance of the developing technologies and have started to develop digital counterparts of the textbook (see Gleerups’ Interaktiva böcker¹). For some time this remained more or less in the domain of the e-book – which has rather similar content as the original textbook.

However, instead of simply imprinting the content on a screen in a computer-friendly format, digital technologies have been recognized to offer great potential in the form of tools (Drijvers et al. 2010). Such tools may include video, audio, interactive tools for manipulating content, direct

links to other knowledge sources in the form of hypermedia, possibilities for customization, even means for communication or collaboration.

One example put forward is people using a visualization program (Zilinskiene and Demirbilek 2015) to assist in the creation of math graphs (a task present in all the traditional textbooks, but only the task, not the means for achieving it).

The domain of mathematics is an example where digital technology might be used to facilitate learning (Jupri et al. 2015) and teaching in the form of different tools (Drijvers et al. 2010; Zilinskiene and Demirbilek 2015). Furthermore, its use can be beneficial to students’ achievement (Li and Ma 2010), enhancing their problem solving skills (Shyu 1999), positively influencing their perception of mathematics (Mushi 2000; Bakker et al. 2015) as well as motivation, engagement and self-esteem (Deaney et al. 2003; Hennessy et al. 2005). However, the presence of extensive possibilities could create extraneous cognitive load (Sweller 2011; Kalyuga 2014) and it is important to use extensive interactivity with caution (Lowe and Schnozt 2014; Scheiter 2014).

Even with technology’s recognised potential to benefit mathematics education, its use in secondary schools falls behind the expectations (Drijvers et al. 2010) and the potential is not always realised (Guin and Trouche 1999; Artigue 2002). An important aspect of effective use seems to be the attitude of learners towards the computer tools (Galbraith and Haines 1998; Pierce and Stacey 2004; Pierce et al. 2007; Reed et al. 2010) and the fact that technology is used mainly for repetitive tasks instead of promoting complex learning (Kirschner and Wopereis 2003; Hoyles et al. 2004; Hennessy et al. 2005; Reed et al. 2010).

As we discuss digital technology it is important to note that its social and cultural aspects create opportunities for participation through shared appropriation of the tools in learning environments (Buckingham 2008). The combination of such tools and practices around them could help adults and youth create an authentic contribution to engagement and participation (Goldman et al. 2008). This means that a new set of teaching techniques with the tools in mind can be developed (Drijvers et al. 2010) and it is likely to be related to existing ones and in line with the teachers’ views (Pierce and Ball 2009). However, there seems to be surprisingly little involvement of school students and their views on the subject (Grootenboer and Marshman 2016).

In this thesis I will adress the lack of involvement of school students with an attempt to involve the learners into the ideation process of redesigning an interactive textbook for mathematics at secondary school level. The design process will be adapted accordingly with the phase of ideation.
1.2 Research Question

My study is guided by the following research question:

1. How could school students be involved in a more meaningful way in the design process of creating Digital Learning Environments in order for interactive textbooks to:
   a. accommodate more tools to facilitate the learning of mathematics?
   b. facilitate the teachers in providing a more varied experience in the classroom?

2. Theoretical Framework

2.1 Defining Interactive Learning Environments (ILEs)

Interactive Learning Environments are computer systems that allow learners to participate and engage actively in the presentation of information in order to learn (Renkl and Atkinson 2007). Interactions in a computer-based learning process refer to actions taken by the learner and the environment and both being mutually dependent (Wagner 1994; Renkl and Atkinson 2007).

2.2 Design of Interactive Learning Environments

Sabry & Barker (2009) assert that the design of Interactive Learning Environments needs to use principles such as active learner’s engagement (Alexander & Boud, 2001), provision of choices, easy ways of navigating, various interaction patterns and usage of multimedia (Evans et al., 2002) while giving feedback and allowing for reflection (Laurillard, 2013).

A learning system consists of four main components – learner, subject content, technology and pedagogy (Sabry 2005):

- **Learner** – all previous knowledge about the student (demographics, styles of learning, performance and attainment levels, attitude towards the material).

- **Subject Content** – relevant subject knowledge according to the curriculum with the materials provided plus information supplementary to the subject material (for example browsing the Internet for more information on the subject).

- **Technology** – the tools to be used and the usability, navigation and human-computer interaction in a learning system. Includes all hardware considerations.

- **Pedagogy** – the way of delivering a course study in terms of instruction – information on learning theories (e.g. constructivism), instructional approaches (e.g. learner-centered), methods and styles of instruction relevant to the subject matter.
The degree of interactivity in a system is dependent on how these components are managed and coordinated. To describe how interactive elements coordinate and balance the above, Sabry and Barker (2009) propose adding an interaction component – decisions and considerations about interactivity level (Sabry & Barker, 2009). After these five major components – learner, subject content, technology, pedagogy and interactivity. Sabry & Barker (2009) propose adding a sixth component concerning the dynamic contents of an ILE to accommodate dynamic updates to the other components.

### 2.3 Interactivity inside an Interactive Learning Environment

For the context of Human-Computer Interaction I will use the classification by Sims (1997) for interactivity as it is referred to and used up-to-date by researchers to describe interactions in a learning environment in terms of technology (e.g. Herrington and Oliver 2000; Domagk et al. 2010; Buckingham 2013; Issa and Isaias 2015).

#### 2.3.1 Levels of Interactivity

Sims (1997) proposes a classification based on elements that can be integrated together in order to make the instructional transactions more comprehensive and engaging. The classification (as presented by Sims) for the types of interactivity is as follows:

1. **Object** – objects (buttons, interactive fields) that are activated by using a mouse or another pointing device.

2. **Linear** – provides the ability to move forward or backward in a linear sequence of instructional material. Does not give response-specific feedback, only access to next or previous display.

3. **Hierarchical** – a common interpretation are menus, which provide options for selection which after selection of an item redirect the learner into a linear interaction and upon completion of a sequence return the learner to the original menu.

4. **Support** – the facility in an application that provides the user with the option to receive performance support, ranging from help messages in its simpler version to complete and complex tutorial sequences and systems.

5. **Update** – initiate a dialogue between the learner and content generated by the computer. For example, the application presents a problem, responded to by the learner. By analyzing the response of the learner, the computer generates feedback. Basing the feedback on learner responses makes the updates appear more individualized.
6. **Construct** – extension to update interactivity that requires the learner to manipulate different components (objects) to achieve a specific goal. Requires extensive design and strategic effort as many parameters affect the successful outcome.

7. **Reflective** – assists to incorporate text responses to prompts or questions. Records each response entered by the user and allows comparison to the answers of other users as well as recognized experts in the field (for example, the rest of the class or a response submitted by the teacher). Provides the learners with the possibility of reflection and to make their own evaluation of its accuracy and correctness.

8. **Simulation** – gives the learner complete control of the instruction with the individual selections determining the whole instruction sequence. Closely linked to Construct interactivity and may require a specific set of tasks to be completed before generating any feedback. Varies a lot according to the specifics of the instructional strategy (e.g. will strongly differ between every subject in school).

9. **Hyperlinked** – provides access to a complete knowledge base and the possibility to navigate at will through that base. Providing linked information can serve as a means to pose problems that can then be solved by correctly searching and finding the solution in a maze of information.

10. **Non-immersive Contextual** – a combination of the various interaction levels into a virtual instructional environment where the learner is given the ability to work in a job-related context. Instead of being in a passive role, the learner is transported into a micro world modeling an existing work environment with all the tasks reflecting those of the work experience.

11. **Immersive Virtual** interactivity (mutual elaboration) – projects the learner directly into a complete computer-generated world responding to individual movements and actions.

### 2.3.2 Dimensions of Learner Control

I will provide and use the classification of learner control by Sims & Hedberg (1995) as it is referenced and used by other researchers up-to-date (Ben-Zadok et al. 2009; Toews and Beatty 2009; Sorgenfrei et al. 2013; Filer 2015) and is one of the more comprehensive and detailed analyses I have found so far on the subject:

1. **Control over content** – referring to selected objectives linked to a specific lesson with no choice which parts of content are displayed. The learner controls which area of content to study and the software presents that content in a predetermined way. Resulting from this fact two levels can be defined – one giving the learner the ability to choose the module of
study and one where the way of presenting the content and the display elements are also controlled by the learner.

2. **Control over sequence** – defined by the order followed when viewing content - the ability to move in and out of content items. Varies if the sequence is moving linear or the instruction implements hypermedia where the movements are non-linear.

3. **Control over pacing** – the pacing at which the software presents the content. Advised to be controlled exclusively by the user as different learners may have different pace of solving tasks.

4. **Context within which to learn** – a subpart of Control over content which deals with the particular options provided to place content into a familiar context after selection.

5. **Method of presentation** – providing options for the methods of content delivery in a strategy to match different learning styles. Possible options might be video, graphics, text or sound.

6. **Provision of optional content** – additional material to be accessed by the learner as they please. Could relate to support or navigation interactions rather than learner control specifically.

7. **Locus of control** – used to determine the amount of learner or program control in the lesson.

Sims & Hedberg (1995) then add a more in-depth view on the dimensions of learner control. The dimensions are described along a line between low end and a high end. The former requiring the least cognitive effort and the latter the most. They are as follows:

1. **Linear – Hypermedia** – usually learners are able to perform a set of different actions to access information, from fairly easy to grasp linear sequences to complex branching of hypermedia links.

2. **Viewed – Constructed** – ranges from simple viewing of content material to completion of tasks involving a more complex effort such as accessing a “toolbox” to find the correct tools and complete the particular tasks.

3. **Discrete – Integrated** – the ways of structuring information affect the actions that the learner must apply and therefore affect the cognitive effort required for the control applied by the learner. Information could be implemented as discrete components that do not associate with a certain context or integrated within the learning environment by offering facilities through which to access information.
4. **Informative – Self-Paced** – depending on the experience of the user (novice or experienced) they require different range of support. This needs to be considered so that the learners may receive the help they need at any particular time.

### 2.3.3 Learner Engagement and Active Participation

Tang (2005) provides a simple classification of interactivity according to learner engagement that divides interactivity in four types – Control, Response, Manipulate and Co-Construct. They are discussed in more detail below:

1. **Control** – the learner is determining actively the content they are receiving – the interaction is providing the control over pace, sequence and form of instruction. The act of giving that control to the user is meant to engage them with self-regulating the learning process.

2. **Response** – engages the learner and encourages involvement by posing a question or activity that requires the learner’s response. The response is analyzed and feedback is issued. Response interactivity is useful to trigger prior knowledge, check learner’s understanding, summarize, extend or evaluate learning (Tang, 2005).

3. **Manipulate** – engages by encouraging exploratory learning – guiding of the learner so that they can arrive at a rule, concept or principle. Tang (2005) defines two types of manipulative activities:
   - **Concept-development** – learners are let to manipulate different elements to discover an inherent concept, rule or principle.
   - **Computation-illustrating** – starts with a presentation of a formula or a rule and then allows learners to vary the variables and observe the changing elements to achieve a deeper understanding of the formula or rule.

4. **Co-construct** – learners need to manipulate objects or different elements of content to arrive at a specific goal. This way they work together with the computer to perform a task or create a product. Relies on engagement by making learning more purposeful and therefore more meaningful. Requires appropriate guidance when necessary in order to help learners complete the assignment.

After clarifying interactivity and the use of interactive learning environments to support active learner participation (Alexander & Boud, 2001), the next step is to look first at active learning of mathematics and then how interactive media have been used in mathematics education through some examples.
2.4 Active Learning of Mathematics

Röj-Lindberg (2001) presented the approach of active learning (Bonwell and Eison 1991) in mathematics which has been discussed to be beneficial for small groups of learners on several occasions (Prince 2004; Freeman et al. 2014; Yuen and Clarke 2015). The approach stresses the necessity of social construction of mathematical meaning and a role of the teacher as facilitator. The learner is viewed as an active problem-solver working individually or in small groups so that connections between multiple forms of representation of concepts in mathematics and real-world situations can be established (Ernest, 1991; Wood, Cobb & Yackel, 1991; Roberston et al., 1994; Dance, 1997; Atkin & Black, 2005).

Röj-Lindberg (2001) accounts that such an approach includes major changes in the pedagogical practices of a mathematics classroom but instruction in mathematics needs to give the learners opportunities to build connections from mathematics to the outside world through active problem-based learning (Gainsburg 2008; Ashgar et al. 2013; El Sayary et al. 2015).

3. Methodology

In the execution of the process for this thesis I will employ user-centered design philosophy with particular focus on participatory design methods.

3.1 User-centered design

As put forward by Norman and Draper (1986), user-centered design aims to involve the end-users into the design process and they are having a major influence on how the design is shaped. In order to simplify the task of the designer, Norman (1988) expresses the essentials into a set of design principles to guide a user-centered design process:

1. Conceptual models.
2. Simplify the structure of tasks, do not overload and be sure the task is consistent.
3. Make things visible.
4. Make things understandable by using graphics.
5. Use constraint to avoid overloading the user.

User-centered design has been recognized to lead to the creation of systems with more effect and products that are more task-efficient while contributing to those products’ success and better acceptance of the end-user (Preece et al. 2002).
In the thesis I will make use of the following fieldwork techniques described by Preece et al. (2002) – background interviews and questionnaires, sequence of work interviews and questionnaires, focus groups, on-site observation and interviews.

3.2 Participatory design

Users will be further involved in the process through participatory design with the framework provided by Spinuzzi (2005) of the three stages of the research – initial exploration of work, discovery processes and prototyping. The methods that will be used in accordance to the different stages are the following:

1. **Initial exploration** – observations, interviews and examination of artifacts.
2. **Discovery processes** – making of meaning out of the work by workshops (Bødker, Grønbaek, and Kyng 1993), organizational toolkits (Tudor, Muller, and Dayton 1993, Ehn and Sjögren 1991; Bødker et al. 1987) and interpretation sessions (Beyer & Holtzblatt 1997).
3. **Prototyping** – the different techniques for iteratively shaping artifacts such as paper-based outline of the screen of a webpage or a product (Ehn & Kyng, 1991), paper prototyping (Novick, 2000) and PICTIVE (Muller 1991b, 1993).

The methods will be utilized in order to bridge the cultural differences between the author and the users and to provide ground for a common language to assist the development process.

The PICTIVE method employs the use of low-fidelity office tools like pens, papers and post-it notes. The methods will focus on prototyping the detailed aspects of the system because the thesis is executed in the form of participatory redesign of an existing product. Details on the exact execution of the methods will be provided in the design process. And at last, participatory design in the past decade has also focused substantially on infrastructuring between different actors (Ehn 2008; Björvingsson et al. 2010; Star and Bowker 2002) in the sense of creating lasting beneficial relationships in society and I will attempt to reinforce the future of such relationship between students in secondary school and Gleerups.
4. Related work

4.1 Integrated Learning Environments in mathematics education

Here I will examine some services and environments designed to help in mathematics education.

4.1.1 MathCAL

Chang et al. (2006) introduced a computer-assisted problem-solving system called MathCAL, based on four mathematical problem-solving stages suggested by Polya (1945):

1. **Understanding the problem** - the system has a “drawing pen” function, which the learner can use to highlight the important information in the problem.

2. **Making a plan** – at this stage, the system provides some possible steps that can be used to solve the problem. The learner selects the most appropriate ones and sequences them. When the learner submits the plan, the system gives feedback in the form of suggestions.

3. **Executing the plan** – the learner constructs a solution tree using the plan generated in the previous stage. Solution tree consists of schemas in which the learner fills in operands, operator and label of the result node.

4. **Reviewing the solution** – the learner writes the answers and the system evaluates the results. Messages appear if there are any mistakes.

Effectiveness of the system was tested by an experiment on fifth grade students - 135 students from four classes in an elementary school in Taipei, who had recently studied four operations. 49 students with low problem-solving abilities were selected and then divided into experimental and control groups. The experimental group used computer-assisted system in eight practice sessions while the control group was solving problems on paper.

Pretest and posttest results indicate that – (a) students in the experimental group showed significantly more improvement than the control group on the posttest, (b) there was a significant difference between pretest and posttest results in the experimental group, and (c) the control group also showed improvement but there was no significant difference between pretest and posttest. MathCAL was able to help students improve skills such as developing and revising problem-solving strategies since it provided different assistance at different stages (Kahveci and Imamoglu 2007).
4.1.2 LaborScale

LaborScale was designed to improve seventh grade student’s word problem-solving skills in learning mathematics using multiple representations such as graphics, symbols and audio (Adiguzel & Akpinar, 2004). The design of the ILE in this study was based on the following principles (Akpinar & Hartley, 1996):

1. The ILE should provide interactive objects and operators, which are visual and can be manipulated by pupils.

2. The ILE system should provide mechanisms for pupils to check the validity of their methods and thus receive some feedback on the appropriateness of their actions in relation to task.

3. As the instruction aims to support links between the concrete and symbolic representation of word problems, the ILE should be able to display these forms so that the equivalence between is apparent. The system should move its presentation modes to the symbolic as the students gain in competence.

4. The ILE should allow experimentation of concepts and procedures in ways that relate to the children’s experiences. In brief, the ILE should be able to support guided discovery as well as directed methods of instruction.

5. The ILE should allow learning to be conceptualized and procedural in its approach, and be capable of adjusting to the task needs of teachers.

LaborScale was designed using an object oriented, direct manipulation approach. It aims assistance in solving mathematical work and pool problems whose solutions require logic and knowledge of proportions among variables. The user interface of the system has two basic windows: curriculum manager unit and student working unit.

Curriculum manager unit is where the teachers set the activities by specifying the problem content and the types of representation. Interaction with the student takes place in the student working unit which keeps record of student progress and where the following tasks can be done:

1. Displaying ratios previously entered in the problems

2. Dragging and dropping the displayed objects and displaying a vertical scale as a result of this

3. Reaching the right answers of the problems by analyzing a horizontal scale depending on the vertical scale

4. Setting audio environment

5. Transition to other problems
To test the effectiveness of the system, a pretest-posttest group design experiment was conducted. One class from a public school and one class from a private school were chosen. Eighty students participated in the pretest of work and pool problems. Twenty seven students were chosen according to their achievement in the three modes of the post-test: numerical solutions, symbolic and graphic representations of solutions.

The instruction began after a twenty-minute orientation and lasted about two hours. Participants were given problems with varying difficulty according to their results in the pretest. They interacted only with the computer. After the instruction, a posttest was conducted. Results indicate significant improvement of student performance for each mode (graphic, symbolic, numerical solutions) (Kahveci and Imamoglu 2007).

### 4.1.3 Hypermedia CD-ROM

An interactive CD-ROM developed using hypermedia tools presented by Sanchez et al. (2002). The aim is to help secondary school students learn diverse problem-solving strategies. At the start of the program the student has two options: Theoretical Foundations, which can be used to examine the main principles and underlying theory for solving problems, and Practical Development, to practice knowledge. Polya’s (1945) four stages of problem solving (comprehension, strategy, solution and confirmation) are followed also in this study. They appear as captions on the toolbar on the top of each screen.

The system includes various types of problems, which can be solved using various types of strategies (graphic representation, particularization to a specific case, simplification and simulation). After the student selects one of the proposed problems, the statement of the problem appears on the screen. The student can either follow the four stages for the chosen problem or use his/her own strategy.
4.1.4 Illuminations

Illuminations is a website providing resources for assisting teachers available at http://illuminations.nctm.org/Default.aspx. It provides assistance in two main forms - Lesson plans and Interactives. The lesson plans are a detailed outline of a lesson including instruction plan, objectives and standards, list of materials (provides links to interactives relating to the lesson if such are present in the Illuminations database), assessments and extensions, questions and reflection and related materials (Fig. 1).

The so-called Interactives are mini-games (Jonker et al., 2009; Panagiotakopoulos, 2011) that present typical mathematical problems in an engaging format for children. The focus of those games is mostly on little children where they manipulate different elements on the screen.

Some are available for students up to twelve grade but most of the games target smaller children. Such games are available through many different channels and services but what makes Illuminations unique in the sense of engagement is what they call Calculation Nation – a sub-service that allows children to play the interactive games against other users from around the world. This is a significant difference with all other services that assist mathematics understanding through games as it utilises communication as a form that enhances learning in both parties involved (Pea, 1994).
4.1.5 Wolfram|Alpha

Wolfram|Alpha is a type of interactive dictionary that not only provides definitions but uses dynamic computation to illustrate the search relying on built-in data, algorithms and methods. What differentiates it mainly from other search engines is that it allows typing of whole mathematical equations and representations to provide the definitions and the result of the calculations which can then be manipulated to observe results.

In order to facilitate typing of mathematical expressions is the use of an extended keyboard with symbols (Fig. 2, a) and allows image input (Fig. 2, b) data input (Fig. 2, c) with different pre-defined categories, as well as file uploads (Fig. 2, d) for data analysis. This greatly facilitate not only the search, but in the form of the extended keyboard also mainly the writing of expressions and data representations which could prove itself extremely time-saving for any environment that aims to facilitate learning of mathematics.

Fig. 2 Wolfram|Alpha (a) extended keyboard (b) image input (c) data input (d) file upload

4.1.6 Desmos

Desmos is a graph calculator that gives the ability to write equations directly using an extended mathematical keyboard that appears on the screen (Fig. 3, a) and allows the user to add a slider to any element in the equation (Fig.3, b) so that the user can then change the variables. The ends of the slider can be defined to limit the function to particular numbers, then the slider can be manipulated so that the user can observe the changes in the equation and the graph or a play button (Fig. 3, c) allows to observe the software then play out the sequence at a predefined pace. If the keyboard proves distracting it can be hidden and then brought up by a small icon in the bottom right corner of the screen.
Desmos is browser based so it can be used without downloading any content which makes it fairly easy to reach and use. Using the system does not require an account but if the user has one they can save and/or share the graphs that they have created. Allows different modes of representation in terms of grid systems and also provides the option for projector view, which is to facilitate use in class. Another way in which Desmos assists teachers is by providing access to pre-made classroom activities that put the use of mathematics in context. They are designed by other teachers in the community and the library that houses the activities is regularly updated.

One such activity is called “Central Park” which lets the learners design parking lots from premade spaces which require the use of specific equations to calculate appropriately. How the activity functions as described by Desmos on [https://teacher.desmos.com/centralpark](https://teacher.desmos.com/centralpark) - “Central Park puts the power of algebra in the hands of students by asking them to design parking lots. At first, students place the parking lot dividers by hand. Then they compute the proper placement. Finally, they write an algebraic expression that places the dividers for many different lots.”

Such activities use Non-Immersive Contextual interactivity which is an advanced combination of other levels (Sims, 1995) and engages through Co-Construct interactivity which is the highest level of engagement as articulated by Tang (2005).

Desmos is a very well executed feature to assist learners and teachers in understanding and presenting equations in terms of interactivity and control but needs to be used in conjunction with other knowledge in order to result in successful learning outcome.
4.1.7 GeoGebra

GeoGebra is a dynamic open-source software for the creation of interactive visualizations of mathematical objects. It has a complete set of tools and views to accommodate different needs and styles to assist learning and teaching of mathematics. It allows the users to create small applications from mathematical equations and expressions which can then be published through tube.geogebra.org with private settings and incorporated into other environments.

This allows teachers to create interactive visualizations in which the students can manipulate variables to observe how the functions perform. Functions in a similar way to Desmos but provides a wider range of tools. This allows it to be part of other environments by providing direct links to pre-made visualizations through tube.geogebra.org (GeoGebratube). It is used in interactive textbooks and lessons to engage users through Manipulate interactivity (Tang, 2005) and provide different Methods of presentation in terms of learner control (Sims & Hedberg, 1995).

GeoGebra offers a very wide range of tutorials and instruction videos to bridge the gap in usability and assist advanced users to get the most out of the service. The GeoGebra is mainly for teachers to implement in their lessons or environments and GeoGebratube is for learners to experience mathematics through advanced interactivity. A view from the GeoGebra interface for creating visualizations is provided in Fig. 4.

Fig. 4 GeoGebra interface for creating visualizations
The use and effectiveness of GeoGebra has been discussed in detail by many researchers (Hugener et al. 2009, Summak et al. 2010, Reisa 2010, Bulut 2010, Zilinskiene and Demirbilek 2015).

4.1.8 Conclusions

After examining these examples it is clear that many resources have been developed and are available to assist teaching and learning of mathematics. However, it seems that the ones available through the web focus either at assisting teachers in a specific area (GeoGebra, Desmos) or at providing learners with access to a complete set of information to navigate at will (Illuminations, Wolfram|Alpha). Others try to encapsulate the experience into a single environment without the need for any external assistance (LaborScale, MathCal, Hypermedia CD-ROM).

Whatever the focus of each example might be, they all rely on active participation by the learner, some of them in conjunction with material prepared in advance by the teacher. The different examples show the use of games to engage (Illuminations), communication to engage in mutual learning (Illuminations, Desmos), providing the possibility to manipulate data to reach a better understanding (Desmos, GeoGebra) and some provide complete control over access to information although generated and gathered by the system (Wolfram|Alpha). Each of the examples excels in a particular task but we could only imagine what using all of them at once will feel like in relation to cognitive load. Nevertheless, they provide a good overview of the tools available and therefore the possibilities to enhance mathematics education through technology.
4.2 Gleerups Interactive Textbook Exponent 1b

4.2.1 Analyzing the current state of Exponent 1b

After clarifying the theoretical framework for looking at ILEs, I will now analyze the interactions at hand in the Gleerups Exponent 1b textbook for mathematics. The analysis and further design considerations will be made on Exponent 1b exclusively since all of Gleerups interactive textbooks for mathematics function in a similar manner and differ only in terms of the curriculum requirements.

The analysis will begin by looking at the five main components of an interactive learning system based on the classification by Sabry & Barker (2009) – learner, subject content, technology, pedagogy and interactivity and observing how they are presented in the product.

First an explanation on how each textbook is received and accessed will be given. The products are received through a service on Gleerupsportal.se which provides the teachers and the students with a hub that houses all textbooks from the company. A textbook is accessed by logging into a personal account and then choosing which textbook to open (Fig. 5).

![Fig. 5 Gleerupsportal.se account view](image)

The textbooks are supplied in two different versions to the end user – Teacher’s textbook and Student’s textbook. This is navigated by the type of account created on gleerupsportal.se – teacher’s or student’s. This provides options to keep record of individual copies of the textbooks. Each student having his own version means that it comes in empty on prior information and tracks individual progress throughout each individual textbook. Due to this the learner component of each textbook is information is empty in the beginning but as the student progresses some information on performance and attainment is accumulated. Those can be
tracked by the teacher, so individual test scores and how many times a student has undertaken a particular test. A note for mathematics textbooks is that they are used in schools as a textbook in the traditional sense of mathematics instruction as given by Lerman (1993). The teacher is leading the lesson and is responsible for articulating everything in connection with learning. This leads to the provision of the Subject Content component – the teacher receives an extra page called The Teacher’s Guide containing the relevant information on the curriculum, all materials, further practice, etc. (Fig. 6).

The technology and pedagogy components are managed in the Settings menu with help, support and instruction videos on how to use the textbooks (Fig. 7).
Gleerups also provides regular video seminars (Webinars) for teachers on how they can implement the textbooks better in their teaching, also hosted through Gleerupsportal.se. It is safe to say that the interactivity component is also managed by these videos and webinars since they provide a very good overview for the teachers and are extremely time-saving and helpful for understanding the technology and interactions in detail. Students can also look at instruction videos but the Webinars are for teachers only but schools could contact Gleerups to book an exemplary session for a class. A lot of explanation and introductory guided tours are possible but usually in practice schools rely on teachers to explain and show to children. This means that students use mostly functionalities from the book that the teacher has explicitly shown or they have discovered by themselves (more information is provided in the chapter of the thesis describing the workshops the author has conducted with students).

The next step is to look in more detail at the interactivity levels and the dimensions of learner control present in the textbook Exponent 1b by using the classification by Sims (1997) for interactivity, by Sims & Hedberg (1995) for learner control and by Tang (2005) for learner engagement. Let’s first look at the navigation used in the textbook and the interactive buttons present on every screen. Regardless of where in the textbook the current screen is positioned, there are two buttons on top of the screen (Fig. 8).

![Fig. 8 Exponent 1b: My site and Menu](image)

The one on the left is “My site” which directs the user back to their account on Gleerupsportal.se where they can switch between textbooks and the second one is “Menu” which activates the appearance of a header containing six buttons which provide general functionalities within the textbook chosen currently (Fig. 9).

![Fig. 9 Exponent 1b: Menu header](image)

The buttons are the following (in order of appearance from left to right) - content, search, listen, notes, my history and settings. Those buttons are a good example of the Object interactivity - they are activated by hovering the mouse over and clicking on them which then transforms each one into an expanded menu or controller providing more options.
Let’s examine their use and how each one performs. Pressing the Contents button opens a menu containing all the screens in the textbook (Fig. 6, a) – it uses hierarchical interactivity to present the contents and then hyperlinked interactivity to navigate directly to a chosen screen with each screen corresponding to a chapter or a subchapter of the textbook. If the user wants to switch screens without using the menu they can use arrows on the left and right on each screen (Fig. 10, b) or swipe the screen (if on a device that allows such interaction) to navigate forward and backward in a linear interactivity (the current screen is highlighted correspondingly in the Contents).

Fig. 10 Exponent 1b: (a) Contents (b) Forward & Backward (c) Support

The Support button (Fig. 10, c) handles the support interactivity where the user can report an error, ask a question or provide feedback or suggestions directly to Gleerups. This is present as overlay on every screen, like the arrows.

Next is the Search button which gives the option to search for anything of interest either in the textbook or directly in Wikipedia, Google or a Dictionary (Fig. 11).

Fig. 11 Exponent 1b: Search
The third button is Listen which activates a plugin that reads out loud all the text on the screen with options for customization (Fig. 12).

Fig. 12 Exponent 1b: Listen and options for customizing the voice over

The next button is Notes - provides an overview of all the notes that have been left in the book and gives options to comment on them or upload files or links to the notes (Fig. 13, a). Notes are categorized by each screen in the textbook since they are left by a button on the top right of each screen (Fig. 13, b) and are therefore tagged according to the screen.

Fig. 13 Exponent 1b: Notes and comments

The notes are a tool for leaving notes for personal reminders or discussion that could happen in the textbook as they give the option to be visible only to the user writing the note or to everyone in the class. The next button is My History which gives the option for the user to leave reminders or comments for him/her-self regardless of the screen they are currently on (Fig. 14).
A search through the log is also possible for easier navigation. Both Notes and My History are defined as object interactivity in its normal use and hyperlinked interactivity when performing a search in the History or clicking in the tags in the Notes.

The last button in the header is Settings which allows the user to customize the layout of the text, upload resources to apply to notes and comments and access the support (Fig. 15). It is again using object interactivity to access the different parts of the settings menu. The Settings also provide the option for network optimization. Gleerups describe its function with the following statement “While active, network optimization will in most cases makes the scroll and page view safer and faster in networks with high load or those with frequent breaks in the connection. When the device is network optimized the swipe function is off. This means that you may use the scroll arrows on the screen to go to the next or previous page”.

The next step is to explore the interactions in a lesson and the different ways interactivity is used to assist learners in better understanding of the material and how exercises function in the textbook.
The way of presenting information is fairly similar to the contents of a printed textbook with the added simplicity of having a whole chapter division together thanks to scrolling. This minimizes the “electronic page turning” (Sims, 1994) to moving forward and backward between whole sub-chapters and chapters. Additional added value is the option to watch videos explaining the material (Fig. 16, a) and to experience a formula and its graphic representations through a service called GeoGebraTube – a visualization tool for mathematical representations previously mentioned in the thesis. The textbook provides a link to pre-made graphics that can be manipulated by the user to observe how formulas and graphics react to change of variables (Fig. 16, b).

Accessing both functions uses object interactivity with the videos being brought up on the screen of the textbook by clicking on the object (Fig. 17) and the GeoGebra image is a link using hyperlinked interactivity to open a new tab in the browser where the graphics can be observed and manipulated (Fig. 18). Though it can be argued that moving away from the textbook screen fragments the experience this is a technological constraint that has yet to be answered. The Listen button in the header is another option provided for a different method of representation of the content to accommodate possible different learning styles and to ease people with certain disabilities.

Fig. 16 Exponent 1b: (a) Video button and (b) GeoGebra presentation
The exercises in the book are divided in two main types - interactive and definitions of problems that are to be solved in an analog manner away from the computer. The latter are presented after each lesson by a button similar to the video material ones only this time labeled “Exercising”. Clicking on the button drops down the definitions of the exercises (Fig. 19, a). Similar buttons follow with “Tips” on how to approach the more difficult ones and “Answers” with the end results of each task (Fig. 19, b).
The interactive exercises are located on a separate screen at the end of each sub-chapter and are accessible directly through the Contents menu (Fig. 20, a). The screen provides tests which are a predefined sequence of tasks which are to be answered on the computer. A test is started by a button in the field devoted to the test (Fig. 20, b).

The tests employ a combination of simple update interactivity in the form of multiple answer questions and presented equations which require only a result to be entered, and simple construct interactivity which requires the manipulation of objects on the screen to match them according to the task. After each question a simple update interactivity is added when the textbook provides feedback on whether the answer was wrong or right and in order to continue in the test the user must press a button. Results are tracked and a teacher can access the results of each student and how many times the test has been taken. Students can also track their results and see how far they reached and how many attempts they have made which is a very simplified form of reflect interactivity.

Fig. 19 Exponent 1b: a) Exercising and (b) Answers

Fig. 20 Exponent 1b: (a) Contents link to the test (b) button to start the test
A final step is to go once more through the presented interactivity through the lens of learner control (Sims & Hedberg 1995) and engagement (Tang 2005).

In Exponent 1b the system provides the user with complete control over Content, Sequence and Pacing. The only exception are the tests where the user is given absolute control over the Pacing since progression is signified by a click, therefore activated by the user, and sequence and content are guided exclusively by the system. The Method of Presentation area of control is also vastly controlled by the user which allows students to explore in two of the three different sequences described by Merrill (1994), namely Rule-Example-Practice, Rule-Practice-Example (the system does not limit the learner from the third Example-Practice-Rule, but the curriculum does not accommodate such an exploration at this point).

Provision of Optional Content is an area of control given mostly to the teacher although the learners can still access the Internet freely to look for additional material which means that the system again does not actually limit the user but does not exclusively provide easier access to additional exercising. The presence of support interactivity also means that there is some form Optional Content provided also to the learners but not on the content of actual mathematics instruction. Although with all the control provided to the user the traditional methods of teaching imply that the full amount of control over content and sequence is not exercised by the learners but the teacher instead. The fact that the teacher follows the curriculum as sequenced in the textbook means that there is little actual control by the learners except when taking the tests. Although we can argue that this is not at all due to Gleerups’ learning environment but instead the current methods of teaching.

Determining the locus of control along the four lines of Linear – Hypermedia, Viewed - Constructed, Discrete – Integrated and Informative – Self-Paced (Sims & Hedberg, 1995) the current state of Exponent 1b is as follows:

- **Linear-Hypermedia** – on this line the textbook leans toward Hypermedia, although users can still follow linear sequence for the most part. certain aspects of the book use Hypermedia style exclusively.

- **Viewed-Constructed** – almost exclusively on the Viewed side as everything is predefined by the system, with small exceptions in the tests and the fact that using GeoGebra requires actually accessing other service and manipulating variables, though not for completing a specific task.
• **Discrete-Integrated** – mostly discrete as almost everything is predefined and accessing information through other facilities such as the Contents menu is optional and provided exclusively for assisting and making a search easier.

• **Informative-Self-Paced** – it is safe to say that Exponent 1b is almost exclusively Self-Paced for the purpose of this dimension.

From the classification of engagement interactivity by Tang (2005) the learners are provided with Control interactivity during the instances where they use textbook for exploring and learning content. Response interactivity when taking tests and receiving the feedback in the form of right/wrong which is not extremely engaging for triggering further learning but the type of engagement possibility is still present. When using GeoGebra though they are a subject to Manipulate interactivity which is by far the most engaging as it is encouraging self-driven exploration in the form of computation-illustrating (Tang 2005).

Judging from the presented levels of interactivity, control and engagement we can conclude that Exponent 1b provides a wider spectrum of options in terms of learner-centred instruction than a regular textbook but is largely held back by the curriculum and the simpler forms of interactivity in order to provide a really engaging experience and to put learning in context. Defining areas of interest when attempting to improve the experience and to provide possibilities for better engagement with the content will be discussed next.

### 4.2.2 Defining areas of interest for improving Exponent 1b

As part of the research for understanding interactive textbooks in their current state and before analysing the interactivity in Exponent 1b I have conducted an interview with Gleerups Concept Developer Marcus Ander. The interview was focused on understanding the technology behind the products of Gleerups and their own considerations for implementation of functions to assist the teaching of mathematics.

In this interview Mr. Ander indicates that the use of Gleerups’ products have so far been in a good shape considering the humanitarian sciences but that according to the company the current state of their mathematics product falls short in meeting expectations for interactivity in mathematics education.

He states that currently Exponent 1b and the other math books are providing a slightly improved version of the printed material but that interactivity could be used for a bigger impact through a smarter interface and smarter exercises.
Gleerups’ ambitions are to provide a more consistent and easy-going experience for mathematics students in Sweden. Mr. Ander expresses considerations for problems in areas such as the absence of more dynamic feedback for exercises and the tools needed to solve the problems such as a calculator, also the lack of overview over the content in the textbook, the need for a better visual indication of progress through material and the fact that the current state of the exercising system takes options out of students hands and tends to be leading the experience.

Considering the fact that the textbook still uses traditional delivery of the material, he signifies the need to challenge such an approach and to better exploit the medium of multimedia and interactivity. In the same time provide options for students to approach the digitally delivered content and problems in an analog way outside of the book. Mr. Ander states that a possible step that needs to be taken for challenging the traditional delivery could be to establish a platform that makes it easier for the teachers community to create books made for digital delivery.

Another interest for future development is incorporating a gamification system (using game-design elements in non-gaming contexts – Deterding et al., 2011) in the textbook for better learner engagement.

4.2.3 Conclusions

Considering the main highlights of this interview and the results of the analysis of interactivity + the learnings gained from analysing related work (MathCAL etc) help the author define areas of interest to address when attempting a redesign of the interactive textbook platform provided by Exponent 1b. They are as follows:

- Reducing the cognitive load on the learners when using the textbook:
  - Navigation through the content
  - A better overview of progress and content
  - Feedback for exercises
  - A quicker and better access to tools for solving exercises
  - Creating a more consistent experience with narrowing the need of navigating away from the textbook

- Engagement of the learners:
  - Higher levels of interactivity in the exercises
  - Better possibilities for constructing a deeper own understanding of the material through interactivity
  - Gamification system
• Traditional delivery which could be challenged through:
  – New system for exercise delivery
  – More exercises that allow constructing of own understanding of mathematical concepts
  – Ways to ease authors of textbooks to create for digital delivery

With these points in mind I proceed to validate them with the users – teachers and students, through participatory design methods.

5. Design Process | User Participation

I have conducted two participatory workshops in an attempt to bring the tools for redesigning the textbook back to its users. Participants were six students who have used the Exponent 1b during the past year. The workshops were conducted in Nova Academy school in Simrishamn as an on-site location.

The workshops were executed within a very limited time window of four days between the workshops and with only two hours devoted to each. Each workshop was divided in three parts – open discussion, design (in the form of rapid paper-prototyping), followed by quick reflection on the prototypes. The discussion was focused to understand students’ needs and experiences with the book so that I could evaluate the valid state of the zones for improvement. It gave the students opportunity to discuss areas to redesign. The rapid prototyping was chosen in order to provide them with the ability to explore possibilities in a form of design as “reflective conversation with the materials of a design situation” (Schön, 1983; 1993). Appropriate for the case low-fidelity design tools were used – plain text, free-hand drawing, quick sketches of interface elements and collages of interface organization.

The focus was split between the two workshops in order to devote enough time to each activity for maximum result because of time constraints. The theme for the first workshop was reducing cognitive load and for the second – enhancing learner engagement. To reflect this, the first workshop was planned for the students to work on their own with design tools to organize the visual load personally and in the second they worked collaboratively to produce ideas and then small artifacts to reflect those ideas.

Considering the fact that the content is split between the two workshops I will first describe both workshops and then present the learning outcomes and methodological.
5.1 Workshop One

The workshops started with handing out a set of questions prepared in advance. The questionnaire was given to each student to fill for fifteen minutes. The focus was on the context of use of the textbook. The questionnaire can be found in the Appendix under Questionnaire – Workshop One. I will give a summary of the answers and some highlights. The answers on most of the questions overlap for all the students with small exceptions which will be pointed out.

5.1.1 Summary of the answers

Use of the textbook in math classes – all the students use it in every math lesson and most of the lesson time passes in the textbook. On using it outside of class about half of the students don’t really use it on their own and the other part claim to use it often for homeworks.

Group assignments and communication – most of the students claim to communicate with their classmates when they use the book but this happens verbally and never through the notes and comments function in the textbook. In fact, the notes function is ignored by all of the students. Later they provide more detailed explanations on why this happens. On the other hand most of them use the search function in case they want to look for something specific.

External tools – all the students describe that they use all the tools as examples in the question with the addition of GeoGebra and a calculator. Everyone would like to have a calculator in the software and most of them prefer all the tools to be in the book itself, one student does not regard that as important but would like that GeoGebra opens directly in the book.

Distractions – the participants list mainly the Internet as the textbook is web-based and this provides easy access to other distractive websites. One student describes issues for mathematical tasks as working on a separate paper, no tools in the textbook and difficulties to find where they left off in the book. As for the textbook itself, the lack of full screen, the comment system being too complicated and the answer section not being well placed.

Preferences between traditional and interactive – all of the students prefer the interactive one (both in school and at home) and find it more helpful than the traditional (exception of one student). When asked to give an opinion, they describe it as a “good tool for learning as long as you have a teacher around to ask for help”. One students thinks it is too complicated.

How engaging is the experience - a little engaging but still more than traditional books and two students don’t find difference. For 3 words to describe their experience the results are “effective”, “helpful” and “easy” along with some of them using “modern”, “better” and “works”.


5.1.2 Discussion

The discussion lasted for 30 minutes and was mostly between the students.

In the beginning the students described how their mathematics lessons related to the textbook - the teacher outlines the lesson by using the textbook as reference and showing examples. The students are then left to explore the content. The teacher does not specify homework but instead the students complete a full set of examples and the “Test Yourself” section on a subchapter before moving on.

The students claim the interface feels overloaded especially when trying to find something in the book. In their experience the search does not function well for mathematics. “Useless” is stated for the notes and comments which they find visually overloading in the interface as “only the teacher uses them”. They tend to overlook them because the notification is “hard to identify”. It feels frustrating to use the book because they can’t write after the exercises and there isn’t a full set of math symbols on the keyboard. They were expecting such an option when introduced to the product and have tried but gave up after experiencing frustration.

Frustration was also expressed for the exercises. “There is no real feedback” from the computer. The frustrating part is not getting a wrong answer but the message from the computer being too “one-sided”. Considering the exercises, they explain to like discussing with classmates and/or the teacher and it is harder at home with no help.

The students like the fact that many functions are featured in one place, the videos and the tools but they would expect more interactivity. Now the textbook is used “more or less as traditional ones”. They expect to be able to write notes after the task directly and to save progress easier so they don’t have to use the navigation every time. The overall impression of the book is “a lot of text on the screen” and if some parts are clickable “they still feel like a text wall”. They repeat the Notes and My History as examples but also the Contents menu which they claim feels stacked with things they “probably don’t really use”. When speaking about distractions (mainly on the Internet) some of the participants propose having an offline mode to disable browsing. They would like turning distractions off when they want.

Later when discussing connections between mathematics education and real life situations the students say apart from simple calculations they don’t make contextual links to more complex mathematics (because they “don’t like studying mathematics”). After this the discussion headed towards possible ways to enhance the mathematics classes and the textbook and the participants focused on two different ideas - gamification and communication.
The students bring up an existing gamification system in the school and express considerations that even though they earn experience points, it feels awkward the points are not used. They say having a similar system inside the textbook could be a trigger to go more often into the exercises. Then express ideas such as having a turn-based collaborative game connecting multiple computers with group assignments where everyone takes a turn for part of the group work; mathematical mini games to complete for experience points (they mention Tetris as an example); or just winning customization of background or other trivial trophy as reward.

A chat is brought up when discussing distractions and the Internet and as a form of small distraction to take off the pressure without leaving the textbook. From there the students start discussing ways in which a function like that could be useful in education. Perhaps having a communication “wall where students could post about problems with the exercises” and ask for help; a connection with gamification for “earning experience with answers”; the chat to be between students or to the teacher; giving access to the message wall to the teacher to correct wrong answers.

5.1.3 Activities

The activities were planned to gather insights on the initial thoughts for possibilities to change the product and to better understand how they imagine changes. I only gave an initial explanation of what to do with the tools. After that they were left to use the materials and I was making observations of what they focus on. Two separate activities were planned – both focused on the interface with 30 minutes for each activity.

Interface redesign toolkit – the students were handed printed screens of the textbook along with functionalities like search, notes and table of contents. The students were provided pens, scissors, paper, post-it notes and glue. The task was to use the tools to reorganize the content on the screen to fit a student’s idea of what the interface should include and to isolate the elements that they found distracting or didn’t use. They were also encouraged to include any other functions as tabs or icons and to include brief description in plain text of what they include.
Participatory design approach in math education | Design Process | User Participation

During this activity the students focused to implement ideas from the discussion as a chat - for help and with other classmates (Fig. 21, a), where gamification could be shown (Fig. 21, b) and turning browsing on or off (Fig. 22, a). Concerning organising the content, the students position most of the things on top in the hideable header of the textbook and include a toolbox (Fig. 22, c), a chat, minigames tab (Fig. 22, d). Later they describe that whatever is included it must have an option to be hidden. Some of the students remove the buttons for Notes and My History and replace them with chat.

Fig. 21 Process: (a) chat tab (b) experience indicator

Fig. 22 Process: (a) browsing is on (b) “too many menus”

Fig. 22 Process: (c) toolbox (d) minigames (e) notes directly on screen
Others show updated notes for elements on the screen. The header is used for experience indicator. In Contents menu some remove different screen indicators (Fig. 22, b) in favor of simplified view chapter by chapter while others include minigames and combined Help screen for Tips and Answers (Fig. 23, a) (described as a combination of the aforementioned sections plus instructional videos). Many students include indication of progress through each chapter similar to the one shown in Fig. 23 (b).

![Image of digital whiteboard interface](image.png)

**Fig. 23 Process:** (a) Minigames and Help

**Fig. 23 Process:** (b) progress through chapters (c) digital whiteboard

The idea of a digital whiteboard to draw, write and reflect in the textbook is expressed (Fig. 23 (c), also visible on Fig. 24).

**Blank interface build-up** - with papers, pens, markers, scissors and post-it notes as materials, the students were asked to sketch and organize the interface of the textbook by memory. This way they might include only functions memorable from previous use or important for future use for comparison with the results from the first activity as a base for validation.
Sketches from the second activity indicate a tendency to divide content in areas - exercises, help (examples and explanations, answers), toolbox. This time they reorganise the contents in groups of functions. For example the answers, exercises and explanations occupy a single menu (could be hidden), same goes for extra content as minigames, toolbox and chat. Some have a homepage and quick access to chat with the teacher with smart linking to exercises (instead of notes) and video exchange – the process of solving a task can be examined by the teacher and students could look on correct ways of solving the task. Other participants put Notes in chat toolbar.

Some express the idea for the teacher to distribute individual tasks to the students personalized for areas they need to work on. Various ways of indicating progress appear in sketches - tracking experience through chapters as gamification by including percentage indicators in the Contents. One student replaces bookmarks with indication for note left in the chapter and for an upcoming deadline for this section. They add functionalities while keeping everything in hideable menus so that the screen remains clear of distraction.
5.1.4 Reflection

The students reflected on their proposals and discussed the different new functions looking through the lens of the real lessons. They noted that some things might not be possible in the current education but could still interest them in the mathematics textbook.

5.2 Interview with the teacher

After the workshop ended I interviewed the mathematics teacher at Simrishamn’s Nova Academy, Uffe Holmström. In the beginning, Mr. Holmström insisted to fill the same questionnaire as the students. Then we discussed the main questions and last we talked about the students’ sketches.

He spends about 10 percent of lessons in the textbook and mostly follows the way students perform to help them. He does not use the notes function, only when something in the book needs correction. He would like an easier way to report errors and access to better support.

He never uses the search function as it is not smart enough and it is hard to find something particular, especially exercises. Like the students he finds it “useless” for this. According to him a quick reference system is needed to search and reach content. All his students use Exponent 1b and all of them experience problems with the overview over content.

Concerning assignments, he gives out group assignments on a monthly basis. They are mostly with visualization of expressions and formulas such as statistics. As problems with the content in the book he finds it hard to know he selected the right level of mathematics. In his opinion the biggest flaw is lack of variety in difficulties. He finds a lot of time and space devoted to exercises that are not needed in his practice. He does not need assessment overview because the school has its own system.

On tools, he points out GeoGebra, calculator and spreadsheets but states that he would not prefer them inside the textbook. As distraction he lists finding what he is looking for and that currently it is neither quick nor easy. For usage and helpfulness, Mr. Holmström puts the interactive only slightly above the traditional. Though he prefers the traditional to use in class, he says that he uses the interactive when at home and interestingly enough, he prefers it in a home setting. His final position is that what really matters is the variety of approaches and he finds having two versions useful. For him external tools provide another way of varying activities during a lesson.

When discussing the sketches of the students he is surprised that they focus on gamification and mentions the system in school which in his opinion students don’t like.
5.3 Workshop Two

The second workshop was divided again in three parts – discussion, activities and reflection. This time the participants were five.

5.3.1 Discussion

The 30 minute discussion was on relations with teachers, engagement with the material and using digital media in education.

In the beginning the students explained different ways teachers help them and described their connection with the teachers. One of their main points is not regarding tutors as authority but as more-experienced people and are interested in their teachers’ work. Students say they would enjoy being more involved in the content (planning the lessons or participating in joint activities with teachers). The idea of involving the teacher in the gamification is expressed. They imagine the teacher giving tasks or setting goals and rewarding with experience points or other trophies. When asked about having some tasks outside the textbook they can’t think how this could happen considering the system is located in the textbook.

About engagement they like the math lessons but it feels repetitive as they are the same. They would like different activities and variety. They have problems with finding related content for mathematics and need the teacher to show them.

The next topic are exercises. They propose a “test yourself” after every subchapter to make more exercises in the textbook. Another idea is “random exercise” or randomized test combining exercises from different chapters. When experiencing difficulty with an exercise one student says “If I could write notes directly on the exercises, the teacher could help out on the particular one”. Another student proposes a direct chatbox to the teacher. A third student thinks that having feedback on the exercises that notifies when they did something wrong is a better solution. She compares it to the message received after each task in the tests – “right answer” or “wrong answer” but instead “wrong strategy for this exercise”.

For digital learning materials one student shares a previous experience from another class - they had a guest teacher introducing them to an online course on design for workplaces and learning to be environmentally friendly. The student describes the experience with the following statement – “The subject wasn’t interesting but the thing worked pretty well. In the end I think I actually learned some things cause it was well made.”
5.3.2 Activities

This time the students worked collaboratively on the following activities – a brainstorming with everyone, categorization of results and prototyping an interface solution out of a chosen idea from previous categories. For prototyping the participants divided into two groups each working on a different idea.

**Brainstorming** – using post-it notes to write down ideas and sharing them in the middle of the table to stack up ideas.

Before brainstorming solutions for improvement, the participants were asked to note positives and negatives of the experience of using Exponent 1b. This was done in the same way as the brainstorming and they were given five minutes for each.

**As positives the students list** – “simple”, “easier to use than regular books”, “everything in one place”, “I can continue where I left off”, “helpful”, “easy to learn and simple to use”, “you can’t forget your book cause you never forget your computer”.

**Some negatives were** – “a bit boring, all white and empty”, “messy to find things”, “no videos with advanced exercises”, “you have to write on paper”, “learning new things can be hard through the book”, “no offline mode”, “can’t write answers in the book”, “no calculator”, “easy to get distracted”.

Then the students brainstormed on “How to create an engaging experience from using the interactive textbook?” Some of the highlights from the resulting pile of notes were:


After sorting the ideas in categories, the biggest categories were “gamification” and “communication”. Then the students grouped themselves in two groups each choosing one category. They were given one hour with pens, paper, scissors and glue to prototype solutions.

5.3.3 Reflection

In this part the students presented their ideas to the other group and discussed their choices.

The “gamification” group – the students decided to include team assignments where different teams compete in a tournament, gaining experience points for leveling up and customization of layout to serve as a reward (trophies), completing assignments or individual tasks, finishing the tournament successfully and through special achievements for doing particular tasks exceptionally well. In order to accommodate those their main solution is to include an experience bar and a level indicator in the header of the book. They introduce profile pictures in the top right corner of the header. Clicking on the profile picture reveals a menu with the current Settings button along with all icons for teams, achievements, tournaments, individual tasks and unlockable materials such as putting sunglasses on the profile picture to mimic the popular “cool” emoji. Even though these are numerous features, the students decide to keep all of them in one place and have the option to hide everything so that it does not distract.

The “communication” group – the students worked on finding a fit for a chat inside the textbook. They decide to provide a profile menu occupying the place of the current Settings and which includes not only details and credentials for the chat but also the settings, a tab for overview over progress in the textbook and indication of current level. After trying out different solutions they decide to divide the chat system into two parts – regular chat and question chat.
The “regular chat” is signified by an icon in the header which opens a small window where one can have a conversation with a fellow student or a teacher, with the option to invite more people from the class. The “question chat” is located in the profile menu and functions like a wall with posts where a student could ask questions to the teacher and provide links to problematic exercises. They described that they would provide the option to filter the posts by people so that it is possible to look only at your own posts and not everyone else’s.

5.4 Learning Outcomes

After examining the results and the gathered materials, I conclude that the students do not particularly enjoy studying mathematics but only due to the fact that the learnings feel disconnected from their life, as also pointed out in previous research (see Prensky 2006; Buckingham 2008; Klopfer et al. in Them 2009) and more or less repetitive (see Kirschner and Wopereis 2003; Hoyles et al. 2004; Hennessy et al. 2005; Reed et al. 2010).

The students do not feel particularly engaged in the material, partly as a result of the traditional methods and the previously mentioned disconnect. The teacher aims for active engagement as well but by varying the different approaches to a lesson. The students prefer to be guided by the teacher, as long as they are not excessively distracted by other factors while using their computers. If additional content has to be delivered digitally for mathematics, the students would expect the teacher to be the guiding force and to organize said content.

Another conclusion is that a gamification system could be a valid form of engagement for the students as they bring it out themselves without being prompted in any way and put a lot of focus in this area with the design tools.

The students think for communication (learner-teacher and learner-learner interactions) as an important driving and motivational force for learning.

Overall, the students tend to look at the combination of their book and their computer as a digital space that is home to everything they would need for studying but mediated by a teacher. On the other hand, the teacher regards it mainly as the channel through which to provide information and examples.

In order to ensure a meaningful learning transaction, the design must aim to meet the expectations of both types of users. However, those expectations are not always as the designers envision them, which is why a participatory design approach could prove invaluable in the field of learning and teaching.
5.5 Methodological considerations

A consideration on the activities – there should have been a presentation of what the core aim of the project was before jumping into action. Of course this should have been done in a way that keeps the topic open for the students and does not result in biased outcomes. In the presented way of execution, they remained open but not particularly focused on the tasks in detail. Another option was to narrow the time for the activities so that the students don’t get distracted at the end of the longer periods.

An addition to the activities that I would like to include is to leave space for activities that promote more iteration between versions in the activity. By observing the directions of the iterations, the input from the workshops could result in a more valuable contribution to the next stages of design. This will therefore provide a better ground for planning activities in the future workshops more accordingly and to enhance the dialog between designers and users.

And last but not least – participation should ideally involve all the sides – the teachers, the students and the developers of the product.

6. Design process | Redesign suggestions

The next step before redesigning is to revisit and iterate the noted areas of improvement by mapping out the overlaps and the differences between the perspectives of Gleerups, the students and the teacher. This is shown in Figure 27.

<table>
<thead>
<tr>
<th>Design process</th>
<th>Redesign suggestions</th>
</tr>
</thead>
</table>
| **Reduce of cognitive load on the user** | - Navigation  
- Overview of progress & content  
- Feedback  
- Tools  
- Less text / Hideable content  
- Easier to find content / better search  
- Overview of progress & content  
- Feedback and easier access to help  
- Tools  
- Math keyboard / Writing directly in the book |
| **Learner Engagement** | - Higher interactivity exercises  
- Own understanding of concepts through interactivity  
- Gamification  
- More varied exercises  
- Exercises that are more focused |
| **Traditional Delivery** | - New exercises  
- More self-driven exploratory approach  
- Creating books for digital delivery  
- More involvement in the content  
- Real world connection with mathematics |
| **Teacher** | - Easier to find content / better search  
- Overview of content / difficulty level  
- Variety of the lessons  
- External tools for working |

Fig. 27 Process: Differences and similarities in the noted areas for improvement
With the most overlap being in the Overview over content and finding content in the book either with navigation or a better search this is the first area to be addressed in the redesign.

Since the design is striving for an engaging experience the next thing to work on is incorporating higher levels of interactivity, as well as different ways of managing attention and engaging the learner. Both Gleerups and the students would like more dialogue with the system. This could be interpreted in terms of interacting with the environment as tools for different forms of input and feedback provided by the system to the different inputs. The interest here is to note which parts require more input and feedback in order to determine what tools to provide and the feedback.

Gamification is another area of overlap and the students showed especial interest in the subject but is an area which requires extensive planning on its own, I will only suggest which parts of the textbook to be included and not the design of the whole system. This could be addressed in both gamifying the use of the content inside the book and by including mathematical games or activities. The chosen activities will be such that involve active participation by the class and the teacher, with the computer as a mediator (e.g. Desmos “Central Park”).

### 6.1 Core functionalities

With so many additions to the functionalities and major changes in approaches it is important to keep the design consistent and be sure not to overload the learner (Sweller 2011; Kalyuga 2014; Lowe and Schnotz 2014; Scheiter 2014). This is why it is important to define the core functionalities of the new textbook design before trying out additions in detail.

If the exercising system is to be transformed into a more contextual and engaging one with more interactivity this will bring a lot of new cognitive load on solving the tasks and keeping track of the right tools (Sweller 2011; Kalyuga 2014; Lowe and Schnotz 2014; Scheiter 2014). This is why the exercises require full focus when they are accessed and so does the curricular content, especially if to be supplemented with interactive examples. This signifies that the content can be divided in two main parts – curricular and practice content. My proposal is to follow this division in the design as well by having two core units – a textbook and a workbook.

#### 6.1.1 Textbook unit

The textbook unit is the part of the interactive textbook containing the content of the printed version – all the screens or pages with the instructional information necessary for conducting a lesson and all the multimedia materials provided to improve the understanding of the material - instructional videos and GeoGebra simulations. The Textbook unit is to be used during the instruction and discussion part of a lesson.
6.1.2 Workbook unit

The Workbook unit is the parallel view of the textbook containing all the exercises and the tools. It also includes the tips section containing possible strategies to tackle the different problems and provides more space for a dynamic feedback system. In analog terms it is an appendix to the textbook containing only the exercises combined with the tools, along with the space to fill in the solutions and check and/or submit the answers. The progress through the content and the successful completion of exercises is tracked for better overview of what has already been covered by the student.

6.2 Interactions in detail

Wireframes for the updated format can be found in the Appendix and I will refer to them in my description while providing smaller images with details where appropriate. Gleerups have redesigned their existing platform during the process of my thesis and the wireframes are slightly adapted to their new style.

6.2.1 Navigation, Overview of Content and Search

Navigation – in order to keep the experience consistent I provide a navigational skeleton based on the current organization but having a parallel screen counterpart containing only the practice content. The difference between the current and the new one is shown in Figure 28.

![Current vs Proposed new navigation](image)

Fig. 28 Proposal: Difference in the main navigational skeleton

The current screen view is to be toggled between textbook and workbook by a button on the screen or by pressing Tab (e.g. between Fig. A1 and Fig. A2 for Contents). This solution provides a clear divide on what the focus is on the current screen and is meant to channel attention only to the task at hand.
Overview – dividing the content also makes it easier to show an overview of current progress and content without overloading the screen. The overview of the position of the current screen is provided in the header with icons to signify which chapter the screen belongs to and all the subchapters inside it. Each icon serves as a hyperlink to the corresponding screen (Fig. 29).

Contents menu – I propose the Contents to be reorganized visually with each chapter and subchapter signified by an icon (Fig. A1 for Textbook; Fig. A2 for Workbook). The icons’ hierarchy is by size and they serve as hyperlinks to different media elements (Fig. 30) if in the Textbook or to tests and answers in the Workbook (Fig. 31).
**Search** – the proposal is to tag the screens with their titles so that the users could provide indication in case they need access to a specific part. The tags also includes indication whether workbook or textbook view (e.g. the search can be narrowed to “workbook geometry” in order to find exercises easier). The Search along with any other tools and the Settings are positioned in the extended menu revealed/hidden by clicking its icon (Fig. 32 on the left).

![Fig. 32 Proposal: Icons to acces the menu and the Notes (added in Gleerups’ redesign)](image)

6.2.2 Including tools in the book

**Calculator** – I propose including an interactive calculator such as the one shown in Desmos. It not only calculates the results but provides possibilities for visualization of graphs and other expressions for students to explore by manipulating variables. Since Desmos is an open source platform and is made to be implemented in other services (similar to GeoGebra) the perfect scenario is directly including it in Gleerups’ platform. Accessing the Calculator happens through the extended menu (Fig. 33).

![Fig. 33 Proposal: Extended menu with “Switch to Workbook”, “Contents”, “Search”](image)

![Fig. 33 Proposal: Extended Menu with “Calculator”, “Keyboard”, “Listen” and “Settings”](image)

**Keyboard** – a calculator requires a mathematical keyboard, as seen in Desmos. Including such a keyboard provides variance of inputs which can be used for writing exercises directly in the textbook. It is also accessed through a button in the menu (Fig. 33).

**Feedback** – if the design allows writing of mathematical expressions with the appropriate symbols, the sequences of the solutions can be tracked to provide dynamic feedback. This can be an alert to the user if their execution so far is appropriate by showing a right or wrong symbol at the end of the line they are currently at. For simpler exercises the feedback triggers only at the end (Fig. 34). The feedback could be turned on or off from the Settings.

![Fig. 34 Proposal: Feedback with right/wrong indicator](image)
6.2.3 Engagement and Visual indicators

**Whole class activities** – another option for varying approaches in teaching and engaging the students in the content is to include activities such as “Central park” by Desmos in the Workbook. The advantage of such activities is that they provide clear link between mathematical knowledge and its real world applications in problem-based (Asghar et al. 2013; El Sayary et al. 2015) active learning (Röj-Lindberg 2001; Freeman et al. 2014; Yuen and Clarke 2015). They also engage the teacher and the class in a group activity through the textbook. If Desmos is incorporated they can be selected from the already existing library or created by the teachers. Such activities can be also be regarded as an initial form of gamification mentioned previously.

**Visual indicators** – I propose adding a clear indication for completed chapters by using colors in the icons for the Contents menu (Fig. A4 and Fig. A5). Parts that have not been covered appear grey and completed ones are green. This is shown in the header and when in the Contents menu. The tests after each subchapter can be applied different deadlines by the teacher and when there is such a deadline the test icon turns red (Fig. 35). I have also included an indication in the Contents menu if there is a note in each chapter – signified by a small icon next to the chapter icons (also visible on Fig. 35).

Gamification – my proposal is to use the visual indicators for a test trial to see if having a progress bar (Fig. 35 around the Chapter icons) results in increased interest in the students. Another element might be adding small math games (e.g. the Interactives in Illuminations; see Jonker et al., 2009; Panagiotakopoulos, 2011, Bakker et al. 2015).
6.3 Feedback from Gleerups

In the beginning of September 2015, I had a meeting with Marcus Ander, Per-Olof Bergmark and Jesper Olsson from Gleerups Utbildning to present my proposal and discuss the proposed changes. I will briefly present the feedback I received for each part of the proposal. The redesign of the existing platform is reflected in some of the feedback.

**Navigation and Contents menu** – dividing the content into Textbook and Workbook is an idea they have not considered so far but after some follow-up questions will definitely try for further integration. They plan to reinvent the platform for tablet-first use and this might be problematic because it adds more clicks or taps to the interactions. Nevertheless everyone agrees that it provides focus and room for more complex interactions in each part. They will consider hideable menus again after acknowledging the results from the workshops because in the latest version this feature is removed.

**Tools** – agreement with the positives of adding a calculator is expressed and the company has considered implementing Desmos before and are now willing to revisit this idea. Using the keyboard for other purposes seems like a good fit but whether it will be used for typing in the exercises is up for further investigation, as this might prove problematic on smaller screens. Tracking solutions for the exercises to provide feedback will be considered depending on how the platform is shaping in the future but is a possibility because tracking user actions is already implemented in the textbooks in another form.

**Visual indication** – this is considered to be an easy-on-the-eye distinction and we discussed the possibility of implementing a similar system for each chapter instead of overall view due to considerations for smaller screens. As long as the overview remains clear, more clicks are worth it here.

**Whole class activities** – the idea is well received and reinforces the company’s will to revisit using Desmos. The developers are positively surprised by the possibility of such activities, as they weren’t aware of the existence of similar features in Desmos or other software until now. Implementing such activities would not be too problematic as there is already an existing link between the textbooks of the teacher and the rest of the class.

**Participatory design** – they are extremely surprised by the positive results from the workshops in terms of how well the students understand the product and how their ideas are in line with the product’s end goals. Further interest was shown in how the workshops were conducted in detail and the methodology of participatory design. Mr. Ander expressed high interest to adopt such participatory methods and in working with students in the future.
7. Conclusions

During the process of this thesis I have focused my research at directly contributing to the ideation process of the project of reshaping Gleerups Utbildning’s existing platform for interactive textbooks in a novel way for their company.

I made use of participatory design methodology in order to involve school students into the process of re-designing digital learning materials. This was done in order to further contribute to the future development of such technologies, particularly in the form of infrastructuring between different actors (Ehn 2008; Björvingsson et al. 2010; Star and Bowker 2002) and setting a first step in such relationship between Gleerups and secondary school students in Sweden for future design processes.

I believe involving the end-users into the process is important not only for producing more focused products that contribute to society in a meaningful way but also to bridge the gap in knowledge that in my experience exists nowadays between the development of digital learning technology for secondary school level and it’s application – the students. As pointed out in the introduction of the thesis, previous research put forward that there is little knowledge concerning the voices of students, let alone involving them in the design process. As an interaction designer, I believe that this is a flaw that needs to be examined and addressed in the near future.

Whether the particular methods I have used are the most promising is questionable but nevertheless proved successful as a proof to Gleerups Utbildning for the enormous possibilities of taking design tools to students. In the future I would try to provide and make use of more diverse activities if I am to conduct similar workshops for another project.

However, for a more successful relationship between designers, developers and students the involvement needs to start at an even earlier stage in the execution of such projects. My experience from conducting the two workshops and being in the role of a designer as a mediator between users and developers has showed me that people are willing to collaborate and enjoy being actively involved. I believe this will be a even more positive exchange at an earlier stage.

From my research I have come to the conclusion that providing different tools for facilitation of learning in mathematics is not only a matter of what can be implemented in a system but the implementation of which tools exactly would result in a meaningful exchange between learner and system, learners and instructors and between learners. With so many tools already available it is more important to balance between the ones that appeal to students and those deemed useful by teachers and researchers. Nevertheless, I have found immense interest in students at
secondary school level in video games for exchange between learner and system and in fostering communication in education for the exchange between people involved – learners and instructors. Those findings should not be ignored when addressing a further iteration of the product.

Furthermore, I believe this is where the full effort should be put in the near future in order to establish systems to fully harness this immense potential of gaming (Svingby and Nilsson 2011; Harvard Maare 2015) and communicating (Boud et al. 2014) in learning. This might serve to bridge the gap between young people and adults’ knowledge and interests. There has been a substantial amount of research on the topic (e.g. Klopfer et al. in Them 2009; Nilsson 2010; Svingby and Nilsson 2011; Bakker et al. 2015; Harvard Maare 2015) and I am confident that this is an important step in bringing the different digital generations (Prensky 2006; Buckingham 2008; Tapscott 2008) closer together.

In terms of facilitating the teachers to provide a varied experience I believe that the strength lies in communication and group activities that provide clear relation with outside world concepts.

My research indicates that students are willing to participate with their teachers in creating a more engaging experience from their school attendance and value possibilities to get involved into such action.

If designers, teachers, students and developers participate together into designing engaging technology for secondary school mathematics (and not only), which is to be experienced in a group while nurturing problem solving in clear context, there might be no need to strive for variety through technology. Technology then might be able to go in the background and be a mediator for collaborative knowledge formation. After that merely looking for inspiration out in the world will be able to provide variety in contexts in which to apply mathematical knowledge.

I believe that establishing participation channels for students to collaborate with teachers in finding such contexts is a logical next step for the future of mathematics education and I regard the design of interactive textbooks as a good start for exploring such possibilities of seamlessly merging technology and education in a classroom setting.

The positive feedback that I received from Gleerups Utbildning AB, along with the willingness of the students to get involved, encourages me to think that this is well on its way considering mathematics education. Last, it serves as evidence to me that participatory design is indeed a powerful tool for helping society and one that I intend on using in the future.
8. References


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9. Appendixes

9.1 Questionnaire | Workshop One

1. Name and Age?
2. Profile of study in school?
3. How often do you have classes in mathematics?
4. How often do you use the interactive textbooks in class?
5. How often do you use them outside of class?
6. How much of your class time is spent in the interactive textbook overall?
7. Do you communicate with your classmates in any way when using the textbook?
8. Do you use the notes function of the textbook?
9. Do you communicate with your classmates through notes and comments in the textbook?
10. Do you have group assignments for mathematics? If yes, how often?
11. Do you use the search function inside the book? (in case you use Google on a separate tab but not in the book, please note that)
12. Do you use any external tools when solving problems in or from the textbook (count anything like pen, paper, ruler, other websites or services) If yes, please list them:
13. Do you imagine tools being present in the interactive textbook?
14. List 3 major distractions when solving mathematical tasks?
15. List 3 major distractions when using the interactive textbook?
16. How do you find the interactive textbook compared to traditional ones in terms of helping you learn?
17. Any preferences on which one to use in class?
18. Any preferences on which one to use at home?
19. Do you look in the tips or answers when not sure about something?
20. Any opinions on using the interactive textbook?
21. Do you find the experience of using the interactive textbook engaging?
22. Please list 3 words to describe the experience of using the interactive textbook.
9.2 Wireframes

9.2.1 Contents | Textbook

Fig. A1 Proposal: Table of Contents | Textbook
9.2.2 **Contents | Workbook**

![Table of Contents](image)

**Fig. A2 Proposal: Table of Contents | Workbook**
9.2.3 Contents | Textbook screenview with extended menu

**Fig. A3 Proposal:** Table of Contents | Screen view with extended menu

*Fig. A4 Proposal:* Table of Contents | Textbook with visual indicators of progress

9.2.4 Contents | Textbook with visual indicators of progress
9.2.5 Contents | Workbook with visual indicators

Fig. A5 Proposal: Table of Contents | Workbook with visual indicators of upcoming deadlines

9.2.6 Screenview in the Textbook

Fig. A6 Proposal: Screenview in the Textbook
Fig. A7 Proposal: Screenview in the Workbook