MASTER THESIS

DESIGN OF A SUPPORTIVE WEB-BASED PBL-TOOL

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Note: Wherever is referred to ‘she’ in this report, it should be read as ‘he/she’.

Abstract

Tutors at Stenden University Leeuwarden indicated that during Problem Based Learning-tutorials, students analysed the problem they discuss mostly with the first three methods explained in the learning materials, and did not attempt to analyse with other, to the problem at hand more appropriate, methods described. They expect the cause of this to be in the accessibility of information in the PBL-kit, and in particular with regard to step three of the PBL-process where students have to make a decision on the method the group is going to apply for analysing and subsequently selecting a problem. The aim of this study was to design a web-based supportive tool that stimulates students and tutors to use an appropriate method of analyses (MoA) in step three of the PBL-process and to investigate whether the design of a supportive web-based tool contributes to the selection of an appropriate MoA. The study is design-based, and fits a pragmatic paradigm with use of the generic instructional design model of Plomp. In order to design a web-based PBL-tool that supports the students of a specific program in a specific classroom setting, Rapid Prototyping (RP) was used for formative evaluation, and focused on usability. The overall findings in this study, based on the different evaluations, suggest that the study's final product Prototype B forms a firm base for future design of the web-based PBL-tool as an instrument that is perceived as useful for exploring and selecting MoAs in step three of the PBL-process. They also indicate the application of design guidelines should be an ongoing process of developing and testing, and should keep inciting researchers to investigate and test improvements for the web-based PBL-tool in iterative loops, where variables that influence the use of the web-based PBL-tool, such as proficiency of tutors and students' comprehension of MoAs ought to be included.

Keywords: problem-based learning, educational technology, web-based instruction, 7-step approach

Summary

This thesis reflects and describes the process and product of designing of a web-based tool that supports students at Stenden University in the Netherlands in exploring a problem during problem based learning (PBL) tutorials. PBL is known for learning in a constructivist context, where learning in and through groups by interaction and dialogue is key. This learning environment is characterized by self-directed learning, and also as an unguided/minimally guided instructional approach, which implies that planning and monitoring the learning process is the learner's responsibility.

Although the process of PBL-tutorials at Stenden University is well described with use of the Seven Step Approach (Moust, Bouhuijs, & Schmidt, 2001), even expert users need support of learning materials. These learning materials are available but are regarded as ineffective in improving the quality of the process, especially once students get familiar with this learning environment. Tutors expect the cause of this to be in the accessibility of information in the PBL-kit, and in particular with regards to step three of the PBL-process where students have to make a decision on the method the group is going to apply for analysing and exploring a problem. Therefore, the aim of this design based study was to design a web-based supportive tool that stimulates students and tutors to use appropriate method of analyses (MoA's) in step three of the PBL-process and to investigate whether the design of a supportive web-based tool contributes to the selection of an appropriate MoA.

In order to design a web-based PBL-tool that supports the students of a specific program in a specific classroom setting, Rapid Prototyping (RP) was used as a method for formative evaluation in the design phase and development phases, along with the Instructional design model of Plomp. This research approach was deemed appropriate as it includes contributions of all stakeholders during the design process.

For the initial design of the tool, a list of guidelines was developed based on instructional design theories and HCI theories using the architecture of the existing PBL process, the decision making process, and finally the comprehensive task-analysis of GOMS. Subsequently, the study included two rounds of testing the design.

A group of twelve students tested the tool (prototype A) in the first round and the testing of prototype B was executed by four experts with the use of a standardized checklist with design guidelines. Additionally, two tutors were interviewed about findings from audio-recordings of- and observations by researcher during three PBL-tutorials (meetings) where prototype B of the supportive tool was used. The findings concerning Task Orientation, Information Architecture, and Writing and Content Quality were analysed with use of the checklist derived from the Usability Expert Review checklist. Furthermore a survey among the students that participated in the PBL-tutorials where prototype B was tested, provided insight in the perceived functionality, perceived user interface design, and continued usage intention of the web-based tool.

The first round of testing with users revealed two significant errors in the design, but testers were positive about menu levels, structure of a window, and uniform design of windows and labels. HCI literature provided information to find convenient solutions for the errors in the design and Prototype B was developed by replacing, redesigning, and transferring UI elements. Evaluation of Prototype B in round 2 revealed design issues that were mostly

related to UI: comments and suggestions for improvement from as well HCI experts as student-users were related to the visual design (VD) and the information architecture (IA) of the web-based PBL-tool. In the course of the research it became clear that this perceived UI design influenced the perception of the usefulness, and could therefore have influenced the perceived support of the web-based PBL-tool in selecting an appropriate MoA. The results of the expert student-users survey indicated that the design does support exploration of all MoA's, and it is assumed that selection of an appropriate MoA follows from this support.
The overall findings in this study, based on the different evaluations, suggest that the study's final product Prototype B forms a firm base for future design of the web-based PBL-tool as an instrument that is perceived as useful for exploring and selecting MoA's in step three of the PBL-process. They also indicate the application of design guidelines should be an ongoing process of developing and testing, and that aforementioned issues should keep inciting researchers to investigate and test improvements for the web-based PBL-tool in iterative loops.

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List of abbreviations

CUI	Continued Usage Intention
GOMS	Goals, Operators, Methods, Selection rules
HCI	Human Computer Interaction
IA	Information Architecture
MoA	Method of Analysis
PBL	Problem Based Learning
PEOU	Perceived Ease Of Use
PU	Perceived Usefulness
PUID	Perceived User Interface Design
RP	Rapid Prototyping
UI	User Interface
USat	User Satisfaction
VD	Visual Design

1 Introduction

This report describes process and product with concern to the design of a web-based tool that supports students at Stenden University in the Netherlands in analysing a problem during problem-based learning tutorials.
First the context of the research will be presented, followed by a section where concepts involved are discussed. Formulation of the research goal and research question in section 1.3 is followed by a description of the design approach (1.4). After the relevance of this research is discussed in section 1.5, an overview of the content of the report will be provided to the reader.

1.1 Context of research

The workplace of the 21st century is constantly changing and requires skills that are not only exemplified as logical, analytical, and technical, but also skills that represent communication, creativity, critical thinking, and the ability to work effectively in a team (Germaine, Richards, Koeller, & Schubert-Irastorza, 2014; Bates, 2015). It is the responsibility of educational systems to prepare students for more active and constructive ways of learning in this shift in balance between knowledge and skills, between “knowing how” and “knowing what” (Redecker et al., 2011).

An educational method that meets the aforementioned preparation is Problem-based learning (PBL). It is known for learning in a constructivist context, where learning in and through groups by interaction and dialogue is key. This learning environment is characterized by self-directed learning, and also as an unguided/minimally guided instructional approach (Kirschner, Sweller, & Clark, 2006), which implies that planning and monitoring the learning process is the learners responsibility (Moust et al., 2001).
Some researchers have questioned the efficiency of PBL. For reasons such as that responsibility and autonomy of students is experienced as unstructured, chaotic, and stressful (Kirschner et al., 2006; Duke, Forbes, Hunter, & Prosser, 1998).

Tutors (lecturers that support the PBL-tutorials) and students of the program International Business Administration at Stenden University of Applied Sciences in Leeuwarden (Stenden) recognize the sometimes stressful tutorials, where the quality depends on variables such as composition of the group, content of the problem at hand, and prior knowledge.
An important variable is the knowledge concerning the process itself during PBL-tutorials. Although this process of PBL-tutorials at Stenden University is well described with use of the Seven Step Approach (Moust et al., 2001), even expert users need support of learning materials. Therefore, after a compulsory PBL-training, Stenden provides their students with a booklet that elaborates on the principles and the process of PBL, named the PBL-kit (de Boer & den Dulk, 2010) and a *Blue Card*, displaying a matrix of the Seven Step Method with summarized information of each step in the process (see Appendix A).

Most of the students enrolled do not regularly consult the PBL-kit and consider the “Blue Card” as sufficient guidance in the PBL-process. Tutors however, experience little improvement in the quality of the process, even when students participate for more than a year. They expect the cause in the accessibility of information in the PBL-kit. Particularly in step three of the PBL-process where students have to make a decision on the method the group is going to apply for analyzing and exploring a problem.
Tutors indicate that students work mostly with the first three explained methods in the PBL-kit and do not attempt to analyze with other, to the problem at hand more appropriate methods. They suggest the use of a digital tool where information needed in this step is presented at the right time and in a supportive and guiding format. The assumption is that this tool will have positive influence on the decision making process of students.

This design-based study will therefore focus on improvement of step three of the PBL-process, more specific on the decision making process concerning the application of a method of analysis MoA) during this step. In order to achieve this improvement, a web-based tool will be designed that guides the decision making process towards the most appropriate MoA for the problem at hand.

1.2 Conceptual framework

1.2.1 Problem-based Learning

Research shows that PBL as a learner-centered instructional approach, meets the complex needs of the information age since it focuses on developing real-life skills, such as problem-solving skills as cited in An (2013). PBL guides students in constructing meaningful knowledge during a systematic process and is perceived as useful in higher vocational education. However, Segers, Van den Bossche, & Teunissen (2003) found that several studies indicate an inadequate execution of the analysis phase of the PBL-process.
Students were more focused on solving problems and not on the desired exploration of the presented problem. As a consequence little elaboration on the problem occurred. Hmelo-Silver (2004) indicate that “there may be a place in the process of the PBL model for direct instruction, such as procedural facilitation, on a just-in-time basis”. Such facilitation was implemented by Segers et al. (2003) in developing a supportive worksheet for the steps in the PBL-process. The worksheet directed students towards learning activities and provided them with extensive information. Results indicated that students perceived the learning environment as significantly more positive.

1.2.2 Technology in education

Technology can promote critical thinking, problem-solving, and collaborative learning. In fact, web-enabled learning environments have been successfully incorporated into various disciplines. Donnelly (2005) advocates using technology to support PBL, because technology enables us to build interactive learning environments where students can play an active role in the learning process. Therefore, the use of technology allows students to be actively

engaged in knowledge construction. Cole (2009) highlights the importance of pedagogical design and notes that it is necessary to offer good support in order to keep students motivated and engaged in using technology in learning.

1.2.3 Human Computer Interaction

The web-based tool to be designed in this study comprises the field of Human Computer Interaction (HCI) and should therefore meet design guidelines for HCI, the space where interactions between humans and computers occur, and this interaction is realized by use of a User Interface (UI). Blair-Early and Zender (2008) defined such an UI as the means by which users interact with content for a purpose. They first described four "parameters" essential to govern an effective interface, and then provided a set of ten specific UI "principles" and four general design principles to achieve an effective interface. Spector (2013) stresses that such principles should be designed in alignment and consistency among and across the designed components including content materials, help systems, and guidance of the user.

These parameters and principles can be integrated to establish guidelines that guide design decisions for the web-based tool. Blair-Early and Zender (2008) consider this process as iterative and global and that this approach has great flexibility while accounting for all the relevant factors. Aim of the guidelines is to not only organize material, but also drive inventive development.

1.3 Research goal and research question

Goal of this study is to design a web-based supportive tool that stimulates students and tutors to use appropriate MoAs in step three (the analysis phase) of the PBL-process. To investigate whether the design of a supportive web-based tool contributes to the selection of a to the problem at hand appropriate MoA, design guidelines will be derived from literature, as well as from practice, e.g. users, environment, existing supportive learning materials. The research question can therefore be formulated as follows:

How to design a web-based tool that supports the analysis phase of PBL in order to promote students' selection of an appropriate method of analysis
This research question is subsequently divided into two sub questions:

1. How to apply guidelines for user interface design in designing the web-based PBL-tool?
2. To what extent do users indicate that the design supports the selection of an appropriate method of analysis?

1.4 Design Approach

This design-based research aims to construct a supportive web-based tool for the PBL-process. This study uses the generic instructional design model of Plomp (Verhagen, 2000), often referred to as the ADDIE-model (Figure 1) to define the requirements and parameters

of who the learners are, what they need to know, how they should perform, what skills they need to develop, and how the context may affect the design. The model emphasizes the need to design from an implementation perspective (McKenney & Visscher-Voerman, 2013) and provides room for formative evaluation in a structured process of analysis, design, development, implementation and evaluation of the design. To formulate the objectives of the instruction, the in the Instructional Design Process Model of Smith and Ragan (2005) proposed analysis of the context, learner, and task was applied for this specific setting of PBL tutorials for students of the IBA program of Stenden University (see Figure 2).

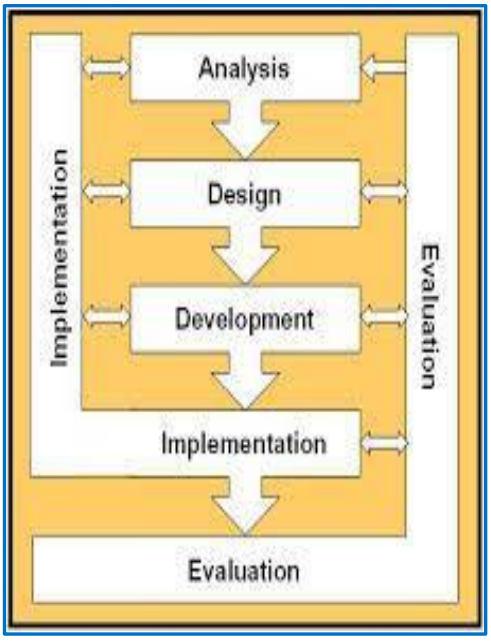


Figure 1. Generic Instructional Design Model of Plomp (Verhagen, 2000)

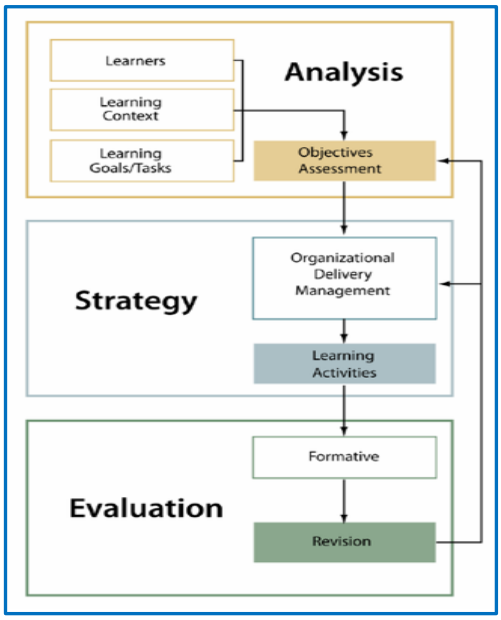


Figure 2. Instructional Design Model (Smith and Ragan, 2005)

The method used for formative evaluation in the design phase and development phases was Rapid Prototyping (RP) described by Tripp and Bichelmeyer, as cited in Smith and Ragan (2005) and Jones and Richey (2000). Rapid Prototyping invites the designer to engage in a fast and repetitive cyclic process of testing and improving an instructional product. RP is valuable specifically in the process of design and evaluation of computer based instruction as a means for reducing the time and cost associated with a full-implementation of an instructional system design model (Daugherty, Teng, & Cornachione, 2007).

Students were requested to evaluate the use of prototype A of the web-based tool and were therefore directly participating in the design of the instruction for the subsequent prototype. This repetitive formative evaluation is seen as a significant advantage of RP (Smith & Ragan, 2005).

In this study, two rounds of testing the design were executed. Concepts and underlying design guidelines, listed in the standardized Expert Review Checklist (Travis, 2014) provided the framework for evaluating the web-based PBL-tool in the evaluation rounds.

A group of twelve students tested the tool in the first round, while testing prototype B was executed by four experts with the use of the aforementioned standardized checklist with design guidelines.
Additionally, two tutors were interviewed about findings from audio-recordings of- and observations by researcher during three PBL-tutorials (meetings) where prototype B of the supportive tool was used. The findings concerning Task Orientation, Information Architecture, and Writing and Content Quality were analysed with use of the checklist derived from the Usability Expert Review checklist of (Travis, 2014).
Furthermore a survey among the students that participated in the PBL-tutorials where prototype B was tested, provided insight in the perceived functionality, perceived user interface design, and continued usage intention of the web-based tool. Answers to the research questions emerged from these evaluations, and recommendations were given for further iterative loops of development and evaluation of the web-based PBL-tool.

1.5 Scientific relevance

This study integrates theory and practice of interaction design to foster the implementation process in PBL- tutorials. Integration of user perspectives into the design and development phase will likely contribute to the usability and effectiveness during implementation.
First evaluation results of this study show to what extend structured and just-in-time web-based guidance during step three of the PBL-process leads to the use of more appropriate methods of analysis, as perceived by students. These results can serve as a starting point for future (design) research to further enhance the effectiveness of PBL as an educational concept.

1.6 Overview of this research

This thesis consists of six chapters, of which the current chapter forms the introduction. The second chapter describes preliminary research, consisting of a context analysis, learner analysis and task analysis, and design guidelines derived from these analyses. In chapter three, design principles and heuristics of instructional design theories and Human Computer Interaction (HCI) theories including their application in the design of the web-based PBL-tool is described. The following chapters explain the process of development and evaluation of the prototypes. Finally, conclusions and recommendations are given in chapter five and six

2 Preliminary Research

In order to design a web-based PBL-tool that supports the students of a specific program in a specific classroom setting, an extensive analysis of the context, learner, and task is a crucial first step that will determine the requirements for instruction (Smith & Ragan, 2005). The methods used for these analyses, results and design guidelines derived from this analysis will be discussed in the sections below.

2.1 Contextual analysis

Analysing the instructional context includes the physical realities, as well as the temporal and social environment that is part of the learning process (Richey & Tessmer, 1995). This means that a thorough exploration of all components involved in the instructional context should systematically be performed.

The first component of the analysis describes the environmental system in which the instruction will be implemented. The second component involves a needs assessment to determine if the development of instruction and subsequent learning is needed and likely to result in the desired performance. The chapter concludes with guidelines for the design, based on the findings from these analyses.

2.1.1 Method

A document analysis of the current PBL-curriculum and learning materials in the IBA program at Stenden University is used to describe the educational environment, the setting of PBL-tutorials and the roles of participants in these tutorials. The needs assessment is based on the discrepancy model suggested by Smith and Ragan (2005), that identifies gaps between the desired learning goals and the goals that are achieved.

Furthermore, two items of an online questionnaire (see Appendix B, items 10 and 12) among the students of the program that specifically show frequency in the current use of the learning materials during step three of the PBL-process, are analysed.

2.1.2 Results

The educational concept of problem-based learning (PBL) is effective in all programs of Stenden University, and therefore extensively supported. PBL-training for tutors and for students is scheduled throughout the academic year and a substantial amount of meeting rooms is utilized for the setting of a PBL-tutorial: round table meeting rooms for approximately twelve students.

2.1.2.1 Setting

The typical setting of a PBL tutorial is a meeting: once or twice a week a group of twelve students are presented with an ill-defined “problem” that has to be discussed and analyzed. In most cases the “problem” is a text and presents a situation that relates to the students

future profession in the field of business administration. After reading the text, the students have to agree on a problem definition and formulate two to five learning questions. This process is called “starting up a problem”. In between two PBL-tutorials, students individually do research and prepare answers to the formulated learning questions. “Rounding off” the problem is done in the next PBL-tutorial, where individual findings are shared and discussed and students agree on the best approach to solve the problem. Logically, a PBL-tutorial consist of two components: starting up a new problem, which is described in the seven step approach of the PBL-process in step one till five, and rounding off the previous problem in step seven of the process.

Roles of students and PBL procedure

During PBL tutorials, students take turns in different roles: chairperson; minutes taker; board writer; observer; member. They have full responsibility for the progress of the meeting, the agenda, time-management, and minutes. Evaluation is done by discussing both the knowledge construction and the group performance at the end of every meeting. The chairperson is responsible for guiding the process and time-management, while the other members are supposed to be more focused on the quality of the content.

Tutor

The meetings are attended by a tutor, mostly a lecturer. The tutor focuses on/must guard the process, the quality of the content, and the methodology. She also ensures that discussions keep on track, she stimulates critical and creative thinking skills and self-directed learning. The tutor conducts evaluations and awards points for active participation, and preferably acts in the background during the meeting.

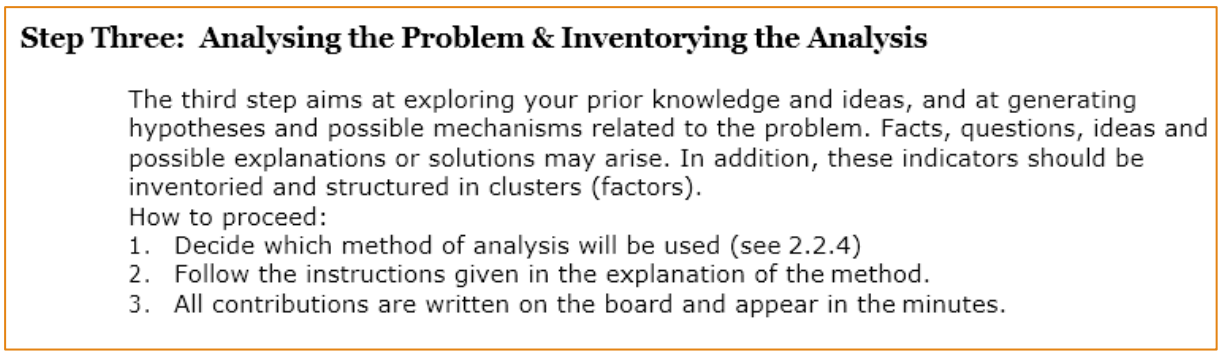
Learning materials

Students are provided with PBL-learning materials when starting at Stenden University. Firstly there is a booklet titled “Stenden PBL-kit” (De Boer & Den Dulk, 2015) with an explanation of the PBL-setting, the educational concept, and with an instruction of the process of the seven-step approach. Secondly, an overview of the steps to take in the PBL-process, including summarized instruction is provided on a sealed card, named the “blue card”. Students learned to work with these materials in the first year introduction program, and the learning materials are consulted for instruction every PBL-tutorial when choices in the process are made or conceptual information is needed.

For in depth information about the educational concept and the procedure of the seven step approach of PBL, students are advised to read the student guide for Problem-based Learning (Moust et al., 2001). A video-clip with general instructions of the process of PBL as it is operationalized at Stenden University is available on YouTube (Stenden University, 2010).

2.1.2.2 Step three of the PBL-process

Further analysis of the learning material concerning step three with the title "Analyzing the Problem and Inventorying the Analysis" of the PBL process shows how students have to explore their prior knowledge by discussing the problem with the use of a MoA. The procedural information of this step and the goal described in the PBL-kit is shown in Figure 3. Students are directed for support in the selection of a MoA to a chapter in the PBL-kit (de Boer & den Dulk, 2015). To accomplish the goal, three sub-goals are described to proceed. This study focuses on the first sub-goal, the selection of one (of seven) method of problem analysis. When asked to comment on attaining this first sub-goal, tutors indicated that students consult the chapter in the PBL-kit often during this step. However, they observed that students are inclined to quickly use one of the MoAs that is explained in the beginning



Step Three: Analysing the Problem & Inventorying the Analysis

The third step aims at exploring your prior knowledge and ideas, and at generating hypotheses and possible mechanisms related to the problem. Facts, questions, ideas and possible explanations or solutions may arise. In addition, these indicators should be inventoried and structured in clusters (factors).
How to proceed:

1. Decide which method of analysis will be used (see 2.2.4)
2. Follow the instructions given in the explanation of the method.
3. All contributions are written on the board and appear in the minutes.

Figure 3. Screenshot of information about step three in the PBL-kit(2015).

of the chapter. Conceptual information about other than the first three MoAs is almost not consulted, and consequently the methods are not used.
The tutors indicate two causes: the first three methods are used during the first semester of year one, so students know how to proceed when selecting these methods, and secondly the students scan only the first three pages of the chapter (nine pages) in the PBL-kit that supports them in selecting MoAs.
According to the tutors, reasons for this behavior are: "they want to get to step five (Formulate Learning Questions) as soon as possible, and reading all conceptual information takes too much time", "hard to direct them towards exploring their knowledge in the broader context of a problem", and "for using other methods of analysis, students lack knowledge of and experience with the methods".

The student questionnaire confirms the opinion of the tutors about the consultation of the PBL-kit in step three. The two items where students are asked to score how often they use the PBL-kit and the Blue Card during a PBL-tutorial in the subsequent steps of the process shows that consultation of the PBL-kit as well as the Blue Card mostly occurs in step three. In Figure 4 and Figure 5 the results of the items are displayed and it shows that of all respondents, 64% consults the PBL-kit or frequently (48%) or always (15%) in step three,

which indicates that there is a substantial need for instruction and conceptual information about the methods of analysis.

	never (1)		not often (2)		frequently (3)		always (4)			
	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Step 1 Explore text and contex..	13x	33,33	16x	41,03	8x	20,51	2x	5,13	1,97	0,87
Step 2 Define the problem	8x	20,51	15x	38,46	12x	30,77	4x	10,26	2,31	0,92
Step 3 Analyse the problem	4x	10,26	10x	25,64	19x	48,72	6x	15,38	2,69	0,86
Step 4 Structure outcomes of...	6x	15,38	17x	43,59	13x	33,33	3x	7,69	2,33	0,84
Step 5 Formulate learning goa...	10x	25,64	19x	48,72	7x	17,95	3x	7,69	2,08	0,87
Step 7 Discuss and report find...	16x	41,03	14x	35,90	6x	15,38	3x	7,69	1,90	0,94

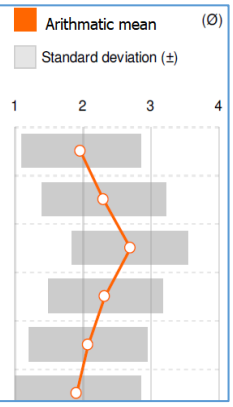


Figure 4. Result of item "Do you consult the PBL-kit in the following step? "

	never (1)		not often (2)		frequently (3)		always (4)			
	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Step 1 Explore text and contex..	9x	23,08	16x	41,03	10x	25,64	4x	10,26	2,23	0,93
Step 2 Define the problem	4x	10,26	18x	46,15	10x	25,64	7x	17,95	2,51	0,91
Step 3 Analyse the problem	2x	5,13	17x	43,59	14x	35,90	6x	15,38	2,62	0,81
Step 4 Structure outcomes of...	4x	10,26	20x	51,28	12x	30,77	3x	7,69	2,36	0,78
Step 5 Formulate learning goa...	9x	23,08	18x	46,15	8x	20,51	4x	10,26	2,18	0,91
Step 7 Discuss and report find...	11x	28,21	16x	41,03	9x	23,08	3x	7,69	2,10	0,91

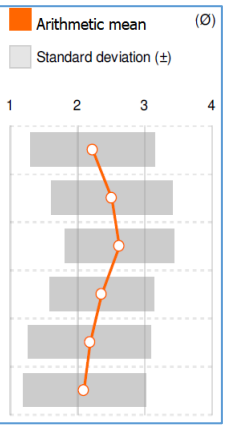


Figure 5. Result of item "Do you consult the PBL Blue Card in the following step?"

2.1.3 Conclusions for design

Tutors indicate that the learning materials are mostly used in step three of the PBL-process, which is confirmed by the outcomes of related items in the questionnaire among students. In step three, students are directed to a chapter in the PBL-kit where they can choose a MoA by reading the conceptual information of each method. Tutors indicate that even by experienced students, the first three methods (of seven) mentioned in the chapter are consulted, and consequently used. Causes they suggest are:

- students started the first semester using these methods and kept on using them (habit)
- reading conceptual information of all methods is too time consuming (time-management)
- students lack knowledge of other methods (knowledge)
- students are not experienced in using the other methods (practice)

An overview of the conclusions and following design guidelines is given in Table 1 on the next page.

Table 1: Guidelines for designing step three based on findings in contextual analysis

Findings	Design Guidelines
Time consuming to browse through chapter of PBL kit when searching methods of analysis	1. Provide students with concise information about each MoA on main UI of step three (no mouse click needed) 2. Provide students with uniform structure in decision making process for each of the methods of analysis.
Methods of analysis are presented in PBL kit in specific order	3. Influence use of MoA by using another than the presented sequence in the PBL tool.
Novice and experienced students don't use other than first three described methods.	4. Display all methods of analysis in main window of step three (no mouse click needed) 5. Uniformity in design and structure of presentation of methods 6. Provide just in time only necessary rules for application of specific method
Both novice and experienced students are consulting the PBL kit in step three of the PBL process	7. Mainly procedural information (concise) displayed in main window (no mouse click needed) 8. Hide instruction that is irrelevant to experienced users 9. In-depth information accessible via buttons with icons in main window
There is lack of general knowledge about the methods of analysis and when to apply the method	10. Provide students instantly of easy to access information (narrative) 11. Use of generic icon for in-depth information for each methods of analysis
Lack of practice in methods of analysis	12. Provide students instantly of easy to access instruction via link to YouTube clip and instructional website (one mouse click needed
Evoking students to explore all methods of analysis; use of indicators in PBL kit did not change behaviour of students	13. Indicators proficiency in PBL and expertise on the topic are left out.
PBL kit informs students that all methods of analysis are applicable to all problems (constructivist educational concept)	14. No error information for selecting a MoA in the design of step three. 15. Attractive presentation of concise information invites students toward more appropriate method for problem at hand.

2.2 Learner Analysis

The features of the web-based tool have to align with students' knowledge, attitude, and skills, and therefore a learner analysis is key and will determine the design of an instruction that is effective for this specific group of learners. Furthermore, the web-based PBL-tool needs to be compelling to the students, and has to offer different approaches to fulfil their learning goals (Gunasekaran, McNeil, & Shaul, 2002). The primary target group of this research is students of the International Business Administration program of Stenden University, who are all familiar with the process of PBL tutorials. The secondary target group is tutors (lecturers) that are guiding the process during PBL tutorials. The issues they encounter and the improvements and objectives they suggest for PBL-tutorials are important in developing an effective web-based tool.

2.2.1 Method

An online questionnaire with eighteen items (Appendix B) among all students of the program (73) provided information about background and relevant cognitive, affective, and social characteristics. Nine items were more specific about students' attitude towards the concept of PBL and the use of a supportive web-based tool. With a response rate of 53 %, the completed questionnaires were analysed (N=39).

Information about the opinions and objectives of tutors concerning the process during PBL tutorials and the introduction of a web-based tool to support the process, was gathered by individual interviews by researcher with three tutors.

2.2.2 Results

Background

The average age of the respondents was 21.5 years, 61% was female. The most represented nationality was Dutch (64%), while other places of origin were Asia, other European countries, and Africa. The majority of students (67%) started this program after graduating from High school in their country of origin and they are non-native English speakers. None of the students had experienced the educational concept of PBL when starting the program of IBA at Stenden University.

Attitude

Respondents' attitude towards PBL shows that 51% is in favour of using the educational concept of PBL, while 23% answers that they really like it and 18% claims to be neutral in their attitude towards the educational concept.

With regard to the use of electronic devices while studying, the results show that at home 97% of the students use their laptop, and at university 85%. Not relevant, but worth mentioning: one respondent uses a book.

When asked what type of device respondents prefer to use during PBL, 15% answered they preferred not to work with a device, 76% would prefer a laptop or tablet. Specific questions

about replacing the Blue Card by an online tool, is positively answered by 77% of the respondents. Their attitude towards replacing the PBL-kit by a web-based tool is not that outspoken: 50% is not sure, because they like the use of the hard-copy version, while 20% is really preferring to use the hard-copy version.

Use of current supportive learning materials

Almost 60% of the respondents is stating that in general they do not (often) consult the PBL Blue Card and 38% answers to use it frequently/always. Similar outcomes are found when asked about the use of the PBL-kit: 67% answers not (often) to consult it, and 33% frequently/always. When the PBL-kit is consulted, the hard-copy version is used (95%) instead of the online PDF-file.

Tutors

Tutors see themselves as a variable in the decision-making process of step three. They indicate that their expertise with regard to the different methods of analysis is influencing the group, and one tutor suggests that there is a need for more instruction for tutors about the methods.

Tutors are positive about the design of a web-based tool and are willing to participate in the experiment. One tutor is reticent about implementation of the web-based tool, because the use of a device could distract students from participating in the PBL-process.

2.2.3 Conclusions for design

The students of the IBA program had no experience in the educational concept of PBL before they started at Stenden University. Nevertheless 74% is positive about the concept. The majority claims to not often use the learning materials (64%), and when they do they use the PBL-kit in hard-copy and not the online PDF file. Most students use their laptop when visiting the university (75%), however when asked their opinion on the use of an online PBL-tool, half of the students states that they are not sure of using it instead of the PBL-kit, while 20% even states that they like the use of the hard-copy PBL-kit.

Tutors are in favor of using an online tool, and because they see themselves as an influencer of the decision making in step three, the suggestion was made to enhance the expertise on the use of appropriate methods for tutors as well as students.

Table 2: Guidelines for designing step three based on learner analysis

Findings	Design Guidelines
Most students (75%) use lap-top at university	16. Design of a tool accessible on lap-top. Responsive website for usability on smartphone or tablet.
20% of students is in favour of using PBL-kit in hard-copy, while 50% is not sure of going to use PBL. Tutors are in favour of using online tool.	17. Integrate short-cut to the text of hard-copy version of PBL-kit (one mouse click needed) 18. Design PBL-kit icon

2.3 Task Analysis

In order to guide the process of designing an instruction that supports the learner, analysing and articulating the ways that you expect the learners to think and act is essential. It follows that the goal of the instruction given to the learner is to reduce discrepancies between the task model of the web-based PBL-tool and the learners mental model of the process (Jonassen, Tessmer, & Hannum, 1999). Comprehensively analysing the tasks should determine the following aspects:

- How is the task performed in the current situation?
- What tasks and skills should be learned?
- What are the goals and objectives of learning?
- Which tasks are most important?
- What is the order in which tasks are / should be performed?
- What are suitable media and learning environments?

Starting point for the task analysis of step three is the outcome of step two, which is described as: “Define a problem statement and formulate a question that reflects the core issue”. After executing step three, students move to step four to structure the information they discussed in step three. Figure 6 shows the architecture of the PBL-process in step two, three, and four.

The main goal of step three is “analysing the problem and inventorying the analysis”(De Boer & Den Dulk, 2015). The first sub-goal described in the instruction is to decide which MoA will be used. The flowchart shown in Figure 7 is a representation of the design that supports the decision-making process that takes place during this sub-goal.

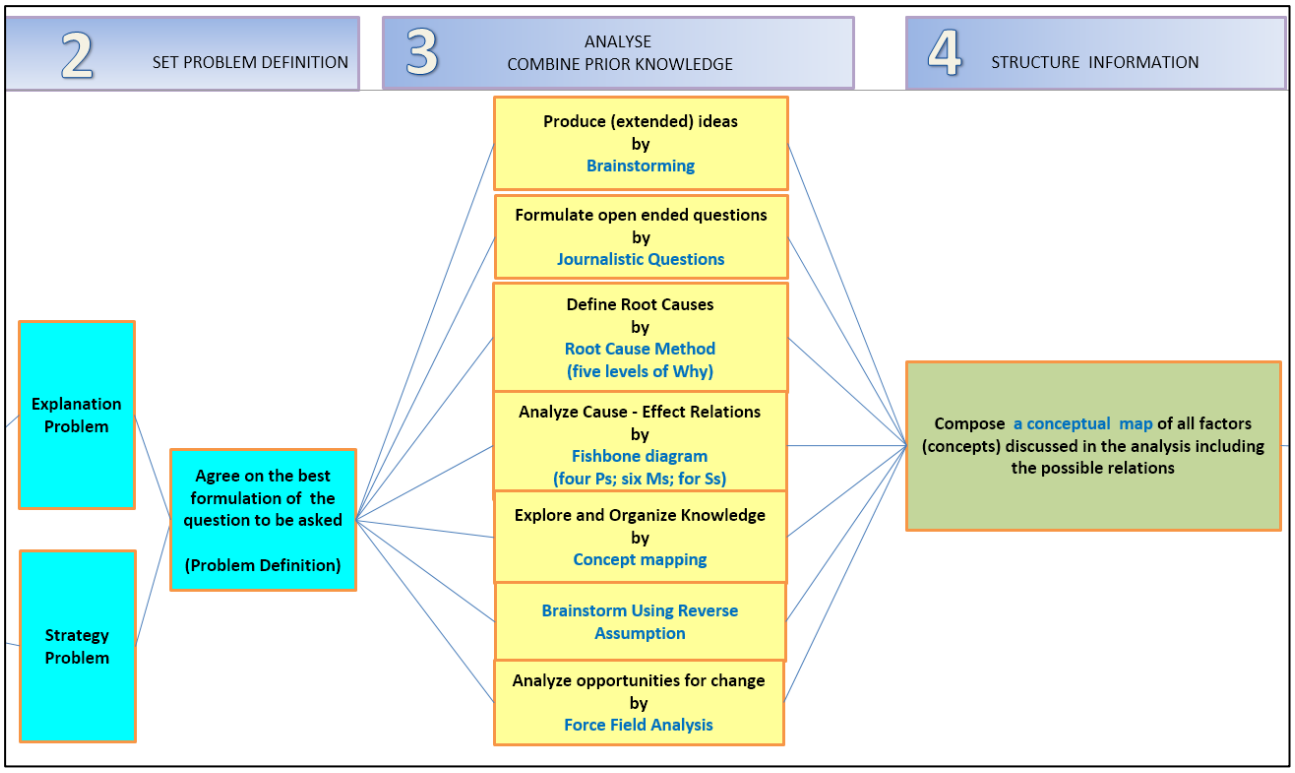


Figure 6. Cut-out of the architecture of the PBL-process (step 2, 3, 4)

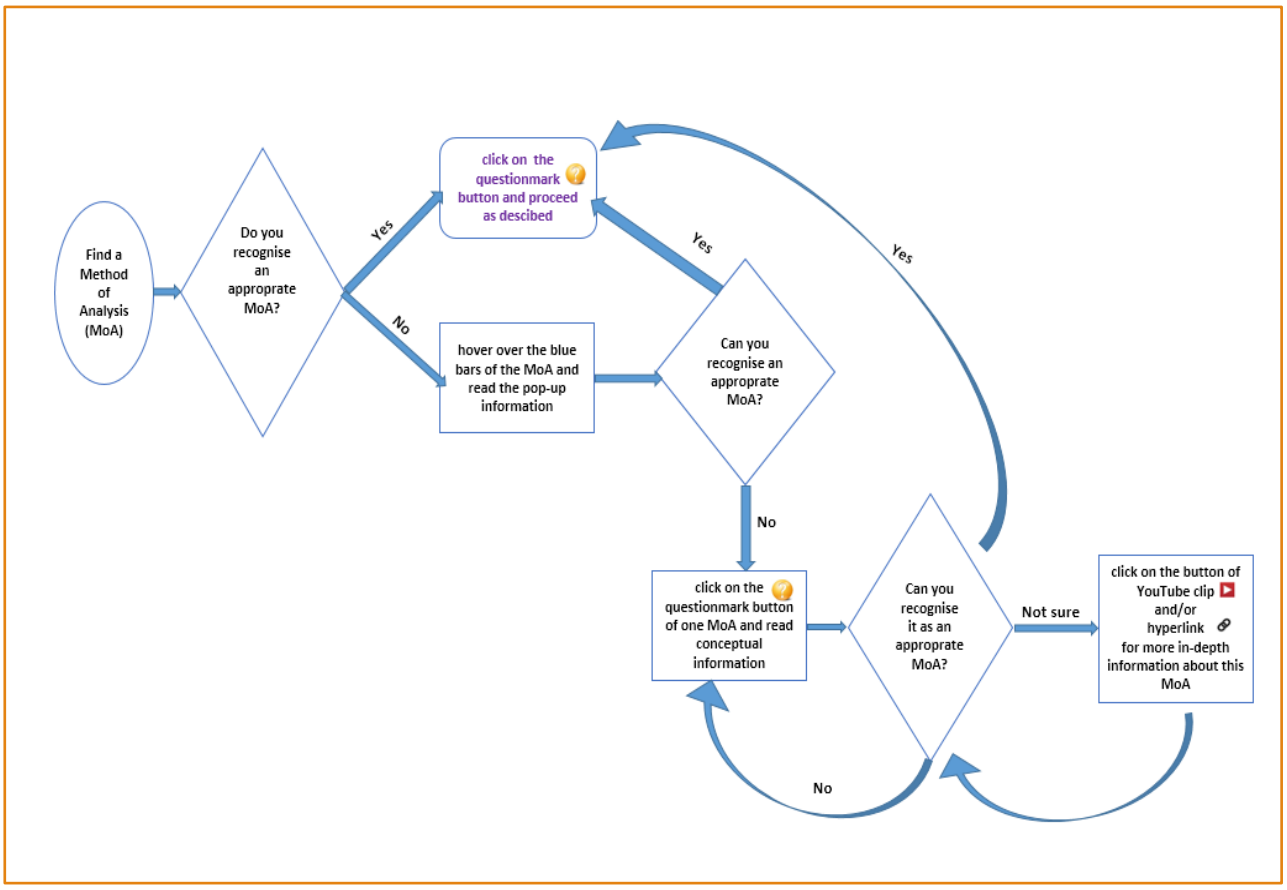


Figure 7. Representation of the design to support decision-making process in step three

2.3.1 Method

To perform a detailed, systematic task-analysis for step three, the GOMS model proposed by Card, Moran, and Newell (1983), which describes the knowledge and skills that are needed to perform a given task. It is the most prominent model in the HCI field and describes very task-specific performance (Jonassen et al., 1999). GOMS (Goals, Operators, Methods, Selection rules) has its origin in analysing routine Human Computer Interactions, and is therefore a feasible model for analysing the tasks in the web-based tool.

GOMS task analysis represents an hierarchical arrangement of four procedural knowledge concepts (see Figure 8): after understanding the Goal of the task, the learner uses Selection rules to determine which Method (that is composed of simpler actions called Operators) is used to attain that goal (Kieras, 1997). Such a comprehensive cognitive task-analysis that models the knowledge and thinking of the students during the procedure in step three of the PBL-process will determine the design of the web-based tool.

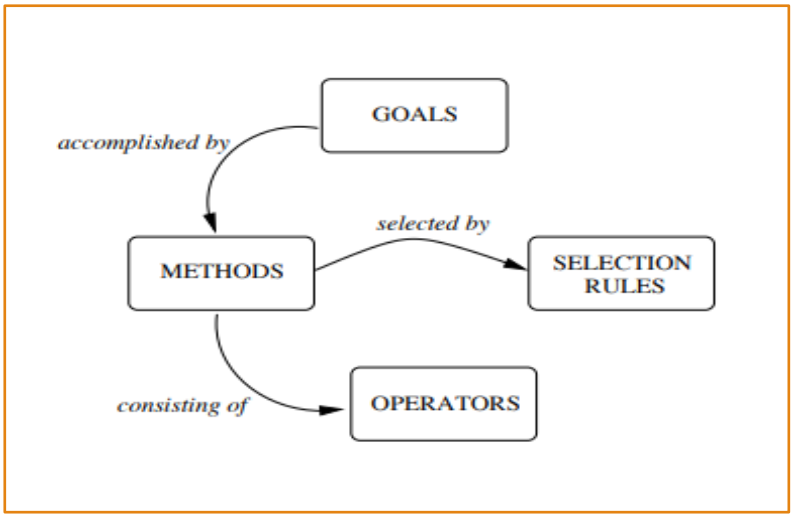


Figure 8. Graphical display of GOMS concepts

In the hard-copy learning materials, conceptual and procedural information is displayed next to each other. Because the study is focusing only on the decision making process in step three for choosing a MoA, conceptual information that is not relevant for this decision making is not analysed in the GOMS model. However, a description of the conceptual information in the existing learning materials is provided in the second part of this section, because it reveals the goals and tasks described by the authors of the PBL-kit (De Boer & Den Dulk, 2015) which can be meaningful for the design of the web-based tool.

2.3.2 Results

GOMS analysis

To attain the main goal described in step three “construct as much knowledge as possible that relates to the problem in its context”, the first sub-goal is “Select the appropriate MoA” which can be divided into three sub-goals, as shown in the detailed GOMS analysis in Figure 9:

- Sub-goal A1 Pre-select an appropriate MoA
- Sub-goal A2 Explore a MoA
- Sub-goal A3 Rounding off the selected MoA

Task analysis step three of the PBL process
with use of GOMS method (Card, Moran, and Newell, 1983)

A	GOAL: CONSTRUCTING AS MUCH KNOWLEDGE AS POSSIBLE THAT RELATES TO THE PROBLEM IN ITS CONTEXT				*
	.	READ INFORMATION BELOW HEADING [ABOUT THIS STEP]			M
	.	READ INFORMATION BELOW HEADING [GOAL]			M
	.	READ INFORMATION BELOW HEADING [TO DO]			M
		SELECTION RULE: IF USERS READ INFORMATION BELOW HEADINGS			
	.	READ INSTRUCTION [1. SELECT THE APPROPRIATE METHOD OF ANALYSIS]			M
A1	.	GOAL: PRE-SELECT AN APPROPRIATE METHOD OF ANALYSIS			
	.	.	HOVER WITH MOUSE OVER BLUE BAR		P
	.	.	READ POP-UP SENTENCE WITH CONCISE INFORMATION		M
	.	.	MOVE CURSOR TO BLUE BAR WITH PRE-SELECTED METHOD OF ANALYSIS		P
	.	.	CLICK WITH LEFT MOUSE BUTTON		K
	.	.	GOAL: PRE-SELECT AN APPROPRIATE METHOD OF ANALYSIS		
A2	.	GOAL: EXPLORE METHOD OF ANALYSIS			
	.	.	MOVE CURSOR TO BUTTON DISPLAYED BELOW METHOD OF ANALYSIS		P
	.	.	CLICK WITH LEFT MOUSE BUTTON		K
	.	.	READ COMPREHENSIVE INFORMATION		M
	.	.	*SELECTION RULE: IF USER DECIDES TO NEED MORE INFORMATION*		
A2a	.	.	GOAL: WATCH THE YOUTUBE CLIP		
	.	.	.	MOVE MOUSE TO YOUTUBE ICON	P
	.	.	.	CLICK LEFT MOUSE BUTTON	K
	.	.	.	WAIT TILL WEBPAGE OPENS (AUTOMATIC START)	R
	.	.	.	GOAL: WATCH YOUTUBE CLIP WITH IN-DEPTH INFO	
	.	.	GOAL: CLOSE WEB-PAGE OF YOUTUBE CLIP		
	.	.	.	MOVE MOUSE TO UPPER RIGHT CORNER ICON [X]	P
	.	.	.	CLICK LEFT MOUSE BUTTON	K
	.	.	.	GOAL: CONFIRM CLOSING YOUTUBE CLIP	
	.	.	*SELECTION RULE: IF USER DECIDES TO NEED MORE INFORMATION*		
A2b	.	.	GOAL: READ IN-DEPTH INFORMATION ON WEB-PAGE		M
	.	.	.	MOVE MOUSE TO HYPERLINK ICON	P
	.	.	.	CLICK LEFT MOUSE BUTTON	K
	.	.	.	WAIT TILL WEBPAGE OPENS (AUTOMATIC START)	R
	.	.	.	GOAL: READ WEBPAGE WITH ADDITIONAL INFORMATION	
	.	.	GOAL: CLOSE WEB-PAGE WITH ADDITIONAL INFORMATION		
	.	.	.	MOVE MOUSE TO UPPER RIGHT CORNER ICON [X]	P
	.	.	.	CLICK LEFT MOUSE BUTTON	K
	.	.	.	GOAL: CONFIRM CLOSING WEB-PAGE	
A3	.	GOAL: ROUNDING OF THE SELECTED METHOD OF ANALYSIS			
	.	.	MOVE CURSOR TO BUTTON DISPLAYED BELOW METHOD OF ANALYSIS		P
	.	.	FOLLOW INSTRUCTIONS UNDER HEADING [TO DO]		M
	.	.	MOVE CURSOR TO BLUE BAR OF SELECTED METHOD		P
	.	.	CLICK WITH LEFT MOUSE BUTTON		K
	.	.	PROCEED TO STEP 4 BY CLICKING ON [NEXT] BAR		K
	.	.	GOAL: ROUNDING OF STEP 3, MOVING ON TO STEP 4		

* = CODES for type of operator	
to press a key or a button	K
to point with a mouse to a target	P
symbolise the system response time	R
mental activity of user	M

Figure 9. GOMS analysis of step three of the PBL-process

Sub-goal A3 “Rounding off the selected MoA” is the only sub-goal that has to be attained before proceeding to the next step in the PBL-process and is done by following the procedural instruction given. The sub-goals A1 “pre-selecting” and A2 “exploring” are used by learner when conceptual information is needed to decide which MoA to use. Variables in the selection of these last two sub-goals are logically how evident the use of a particular MoA is and the proficiency of the learner.

Tasks in step three derived from current learning materials

To structure the process in step three, the PBL-kit suggests to use one out of seven different methods of analysis. Students are directed to the chapter in the PBL-kit, where conceptual and after that procedural information is described for each MoA. The proposed methods are:

- Brainstorming
- Journalistic Questions
- Mind-mapping
- Concept Mapping
- Fishbone Diagram
- Force Field Analysis
- Root Cause Analysis

Information per method is organized in an explanatory part with conceptual information and a graphical representation, followed by an instruction of the procedure, and covers one or two pages per method. The type of instruction in the sub-goals is mostly procedural, however deeper analysis shows throughout the procedure, instruction with an attitude objective (“important to have shared interpretation”) and supportive instruction (“this is where post-its are helpful”).

Errors in decision making

In the introduction of the chapter with explanation of the methods of analysis is explained that “a variety of methods of analysis is described, that are all applicable to use for all types of problems”. An analysis of the description of the methods reveals that the PBL-kit does suggest a particular method for a particular situation, but does not strongly direct students in their choice. Error information does not exist in the instruction of step three.

Completion of the tasks

Completing the tasks in step three will lead logically towards step four. The described action of step four is to transfer the list of all to the problem relevant concepts from step three into a conceptual map, where hierarchy and relationship between the (clusters of) concepts is visualized.

2.3.3 Conclusions for design

The GOMS analysis reveals main goals and sub-goals in selecting an appropriate MoA, which implicates that the design should have a clear hierarchy and division in goals where applicable. Because the web-based tool is supporting experienced users as well as novice users, the design should take into account that only essential procedural instruction and concise conceptual information of step three is displayed in the main window.

In-depth information can be consulted voluntarily and direction towards in-depth information in a chapter of the PBL-kit can be replaced by a click on a button that opens a new window. Providing users of one page with all methods of analysis displayed, is assumingly helpful in choosing the appropriate MoA, and an improvement in comparison with browsing the nine pages of the chapter in the PBL-kit. To evoke students in exploring all methods of analysis, indicators such as proficiency in PBL and expertise on the topic could be left out. This seems reasonable, since the indicators had little effect on the use of other than the methods used in year one of the pro

The web-based tool is characterized as a supportive tool for the PBL-process, the focus of the design should be on procedural information and where needed conceptual information, which implicates that instructions with attitude objectives and encouraging remarks are not applicable in the design.

The PBL-kit is not explicit about errors in selecting an appropriate MoA. To prevent "selecting-error" while using the web-based tool it is important for the design to invite students to the most appropriate one by providing them of just in time concise information about a method.

Table 3: Guidelines for designing step three based on task analysis

Findings	Design Guidelines
Structure with three levels of goals in decision making process	19. Information Architecture of decision making process in web-based tool must follow the structure of three levels of goals.
Methods of analysis are presented in PBL kit in specific order (no prior knowledge to the problem – prior knowledge to the problem)	20. Stimulate use of all MoAs by changing the presented sequence of the PBL kit that students are used to
Attitude objectives and encouraging remarks are not applicable in the PBL process, when tool is used by both novice and experienced users.	21. The design should focus on procedural information and easy to access conceptual information.
PBL kit informs students that all methods of analysis are applicable to all problems (constructivist educational concept)	22. No error information for selecting a MoA in the design. 23. Attractive presentation of concise information directs students toward to appropriate method.

3 Design

In addition to the set of design guidelines based on the analysis in chapter two, design guidelines derived from instructional design theory and Human Computer Interaction theory (HCI) must be drawn up. Since the number of guidelines is substantial, a selection of theories that align with the nature of the web-based tool are discussed in this chapter. To give a structured overview, the design guidelines derived from each theory are numbered and integration of these guidelines into the design of Prototype A is subsequently visualized in screenshots of the UI of step three of the PBL-process.
Before discussing the theories and their implications for the design, the purpose of the design and justification for developing a (responsive) website is explained.

3.1 Purpose

Novice and experienced students of the program will use the tool that replaces the instruction of the PBL-kit and the PBL Blue Card, learning materials that are compulsory for all PBL-tutorials. The provided information is both procedural and conceptual. The tool should therefore be designed both as a tutorial that shows the instruction for the tasks to perform, as well as a reference guide with in-depth (including background) information. The design should support students in their choice of the most appropriate MoA in step three in every PBL-process. Besides procedural information such as a title, a well-defined goal and tasks to be executed, conceptual information related to each method should be provided.

3.2 Justification for design of a web-based tool

As stated in the learner analysis, most students use their lap-top when they are at university and therefore it is desirable to design a tool that is accessible via their lap-top. Additional decisive advantages for building a web-site came forward after comparison of different platforms: features such as immediate access and sharing for all users, compatibility across different devices, reach, life cycle, ease in instant update, no user management, and time and cost-effectiveness.
Condition for a satisfactory usage of the website is the responsive design, whereby structure, size, and media adapts to the view needed on a specific device (Pannafino, 2018). This is according to Baturay and Birtane (2013) a significant feature when users are studying instructional websites.

3.3 User Interface Design Theories

The web-based tool to be designed in this study should meet HCI design guidelines. HCI is the space where interactions between humans and computers occur, and this interaction is realized by use of a user interface (UI). The importance of a well-designed UI for education is stressed by Crowther, Keller and Waddoups (2004), who state that the impact of a poor interface design in education is more serious than in business. It impairs the student's overall

motivation, as well as their learning performance, and has serious moral and ethical implications.

Blair-Early and Zender (2008) define an effective UI as the means by which users interact with content to accomplish a goal. They developed a set of ten specific UI design principles and four general design principles (see Table 4). How the principles are integrated in the design of prototype A is shown in Figure 10, where (numbered) examples of application of heuristics are given next to the screenshot of the UI.

Table 4: Overview of design principles for a computationally based user interface (Blair-Early & Zender, 2008)

#	UI design principles	Heuristic
1	Obvious start	Design an obvious starting point
2	Clear reverse	Design an obvious exit or stop
3	Consistent logic	Design an internally consistent logic for content, actions and effects
4	Observe conventions	Identify and consider the impact of familiar interface conventions
5	Feedback	Design tangible responses to apt user actions
6	Landmarks	Design landmarks as a reference for context
7	Proximity	Design interface elements in consistent proximity to their content objects and to each other
8	Adaptation	Design an interface that adapts or is adapted to use
9	Interface is content	Design interface elements that minimize interface and maximize content
10	Help	As necessary, provide a readily accessible overall mechanism for assistance
#	General design principles	Heuristic
11	Subject matter	Make subject matter obvious from the start
12	Interface visualization	Use visual form apt to the content to embody the interface
13	Content + form	Design apt visual form based on content
14	Metaphor	Use metaphors where content is new, obscure, or a narrative based visual metaphor

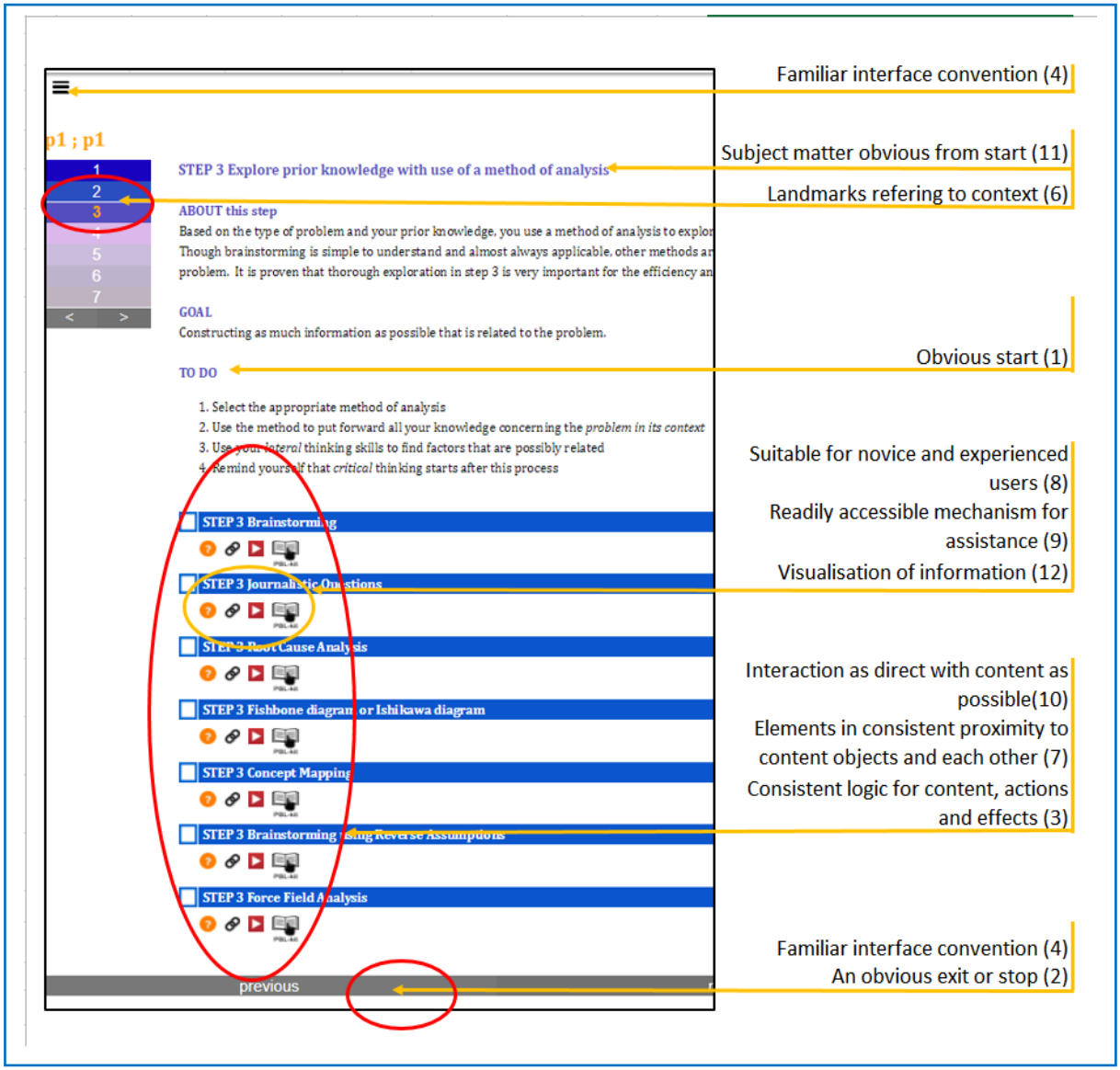


Figure 10. Examples of integration of the design principles derived from Blair-Early & Zender (2008) in UI of web-based tool.

This list of principles and design guidelines has been complemented with a set of usability heuristics drawn from the ISO 9241 standard for ergonomics of human system interaction (ISO, 2006). The seven principles that emphasize the suitability of the UI for the cognitive abilities of the users, a feature that is crucial in design of an interactive system (Coe & Neufeld, 1999) is displayed in Table 5 .

Although the type of information of these principles is a general guidance and has a more informative than normative character, the principles are intended to be used in the design as well as in the evaluation of UI (Hamborg, Vehse, & Bludau, 2004). Figure 11 shows the integration of these dialogue principles in the design of the UI in step three.

As mentioned in the introduction, evaluation of the web-based PBL-tool will be done with use of the standardized checklist that is based on this ISO 9241 standard and composed by Travis (2014).

Table 5: Dialogue principles of ISO 9241 part 10 (2006)

#	Principle	Description
15	Suitability for the task	The dialogue should be suitable for the user to realise his tasks effectively and efficiently. Only those parts of the software are presented, which are necessary to fulfil the task.
16	Self-descriptiveness	The steps to take are understandable in an intuitive way. An adequate support should be offered on demand.
17	Controllability	The user should be able to control and influence the pace and sequence of the interaction till she reached the goal.
18	Conformity with user expectations	The dialogue should be consistent, complying with the characteristics of the user, e.g. taking into account the knowledge of the user, accounting education and experience as well as commonly accepted conventions.
19	Error tolerance	The dialogue is error tolerant if the intended deliverable is reached with no or just minimal additional effort despite of obvious faulty steering or wrong input.
20	Suitability for individualisation	The dialogue should give room for customisation according to the task as well as regarding the individual capabilities and preferences of the user
21	Suitability for learning	The dialogue should support learning, by accompanying the user through different states of her learning process and the effort for learning should be as low as possible.

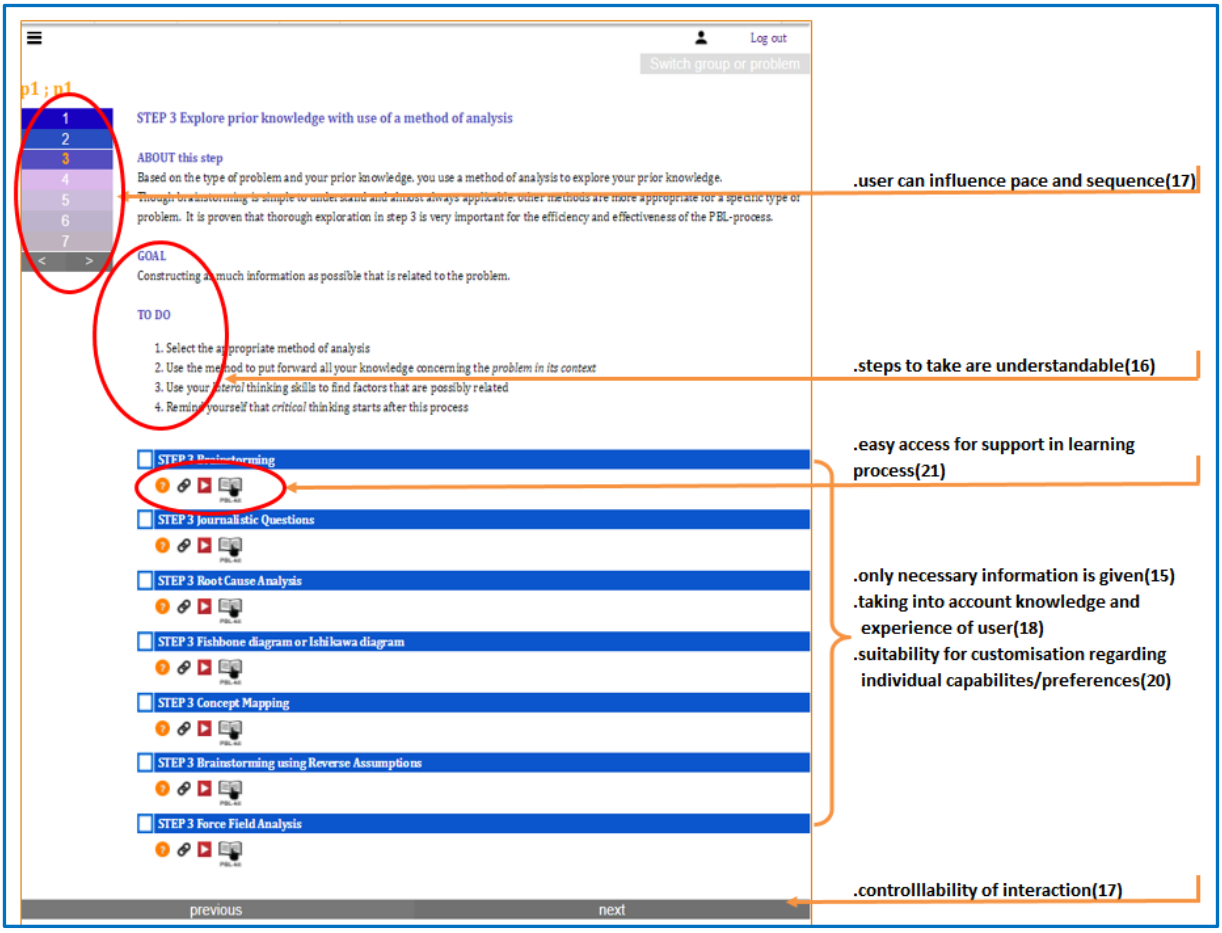


Figure 11. Examples of integration of the design principles derived from ISO 9241 10 in UI of web-based tool.

3.4 Minimalist Design Strategies

Another set of guidelines came from minimalism (Van der Meij and Caroll, 1995). The basic notions are that user support should be action oriented; should encourage and support user exploration and innovation; respect the integrity of the user; address user error. The list of all principles and related heuristics that were described by Van der Meij and Caroll (1995) is shown in Appendix C.

As Van der Meij (2007) states, minimalist design has always emphasized a just-in-time delivery mode, often in combination with the strategy of giving "just enough information". To accomplish this design, information should be delivered only when the task it refers to has to be performed, and only when the user needs the information. The strategy is proven to be effective especially for conceptual information, such as in-depth information about the methods of analysis in step three of the PBL-process.

The application of the aforementioned strategy is crucial in the design, since the web-based tool will be used every week during PBL-tutorials by both novice and expert users. It follows that in-depth information easily can be ignored by users that don't need it. Therefore the UI provides concise instruction and in-depth information is hidden behind buttons. Table 6 displays how heuristics of the minimalistic approach were converted to guidelines for the design of the web-based tool, and an example of the integration of these guidelines is shown in Figure 12.

Table 6: Heuristics of Minimalistic Approach and application in the design

Heuristics of Minimalistic Approach	#	Applied in the design:
Provide an immediate opportunity to act	22	Start UI with title and description of goal
	23	A "TO DO" heading followed by instruction in steps that all start with a verb, is provided on every UI in identic design (main window and sub-windows)
Encourage and support exploration and innovation	24	Provide users with the possibility to explore in-depth information about specific methods of analysis by links to relevant YouTube clips and websites
Be brief; don't spell everything out	25	Headings direct user towards instruction
	26	Use of concise (numbered) information per step
	27	In-depth information is hidden behind uniform icons.
Provide closure for chapters	28	Instruction on using buttons previous/next is given as final instruction on every UI including information on proceeding to next step
	29	Instruction on closing the windows is given where applicable [X]icon

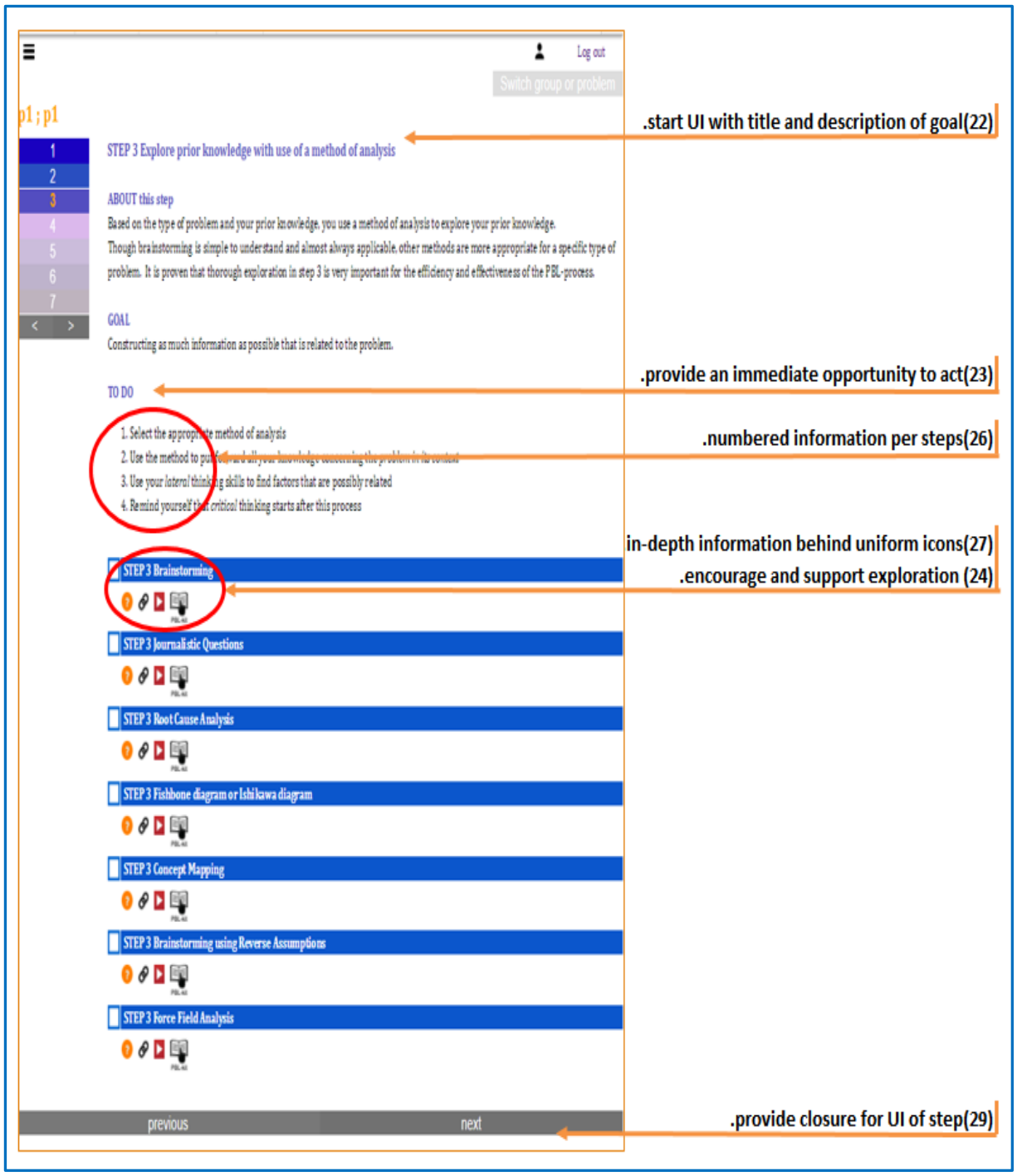


Figure 12. Examples of integration of the design principles derived from minimalist design strategies (Van der Meij & Caroll, 1995)(Van der Meij, 2007)in UI of web-based tool.

3.5 Procedural instruction

According to the minimalist approach, the Four Components Model (van der Meij & Gellevij, 2004) offers useful guidance for procedural instruction. The model identifies the following components of a procedure: Goals, Prerequisites, Actions and Reactions, and Unwanted States (divided in warnings and problem solving information). For each component, the model provides designers with pragmatic guidelines that are firmly based on research.
Guidelines used in each UI of the methods of analysis in step three are listed in Table 7. How the guidelines are applied in the design of the UI of all seven MoAs is displayed in a screenshot of the MoA Root Cause Analysis in Figure 13.

Table 7: Guidelines of Four Components Model and application in the design

#	Guideline	Applied in the design
Guidelines for designing goals		
30	Describe a goal with the aim of selling it to the user	Action oriented statement (start sentence with verb)
31	Paraphrase instead of repeat	Title and goal differ slightly
32	Present the goal task-oriented, in gerund form	The general goal and goals in methods of analysis are written in gerund form
33	General action leading to the goal must be presented	The descriptive sentence starts with a verb that indicates the goal.
Guidelines for design of actions and reactions component of a procedure		
34	Balance direct instructions and invitations to explore	The heading “Tell me more” invites users to explore in-depth information. A numbered list of actions per method is given.
35	Prepare users well before inviting exploration	After clicking the [MORE INFO] button, users find an instruction.
36		Users are invited to explore additional information, by clicking on hyperlinks.
37	An action step always includes a combination of action-object	All steps in the instruction of the methods are built in the action-object mode.
38	Number in sequence, when series of action steps must be completed	All steps in the instruction below headings “To do” are numbered and do not exceed nine steps.
Guidelines for designing problem-solving information		
39	Present problem-solving information immediately after the action step	E.g. clicking [next] without making a compulsory choice, the tool provides you with information to solve this.

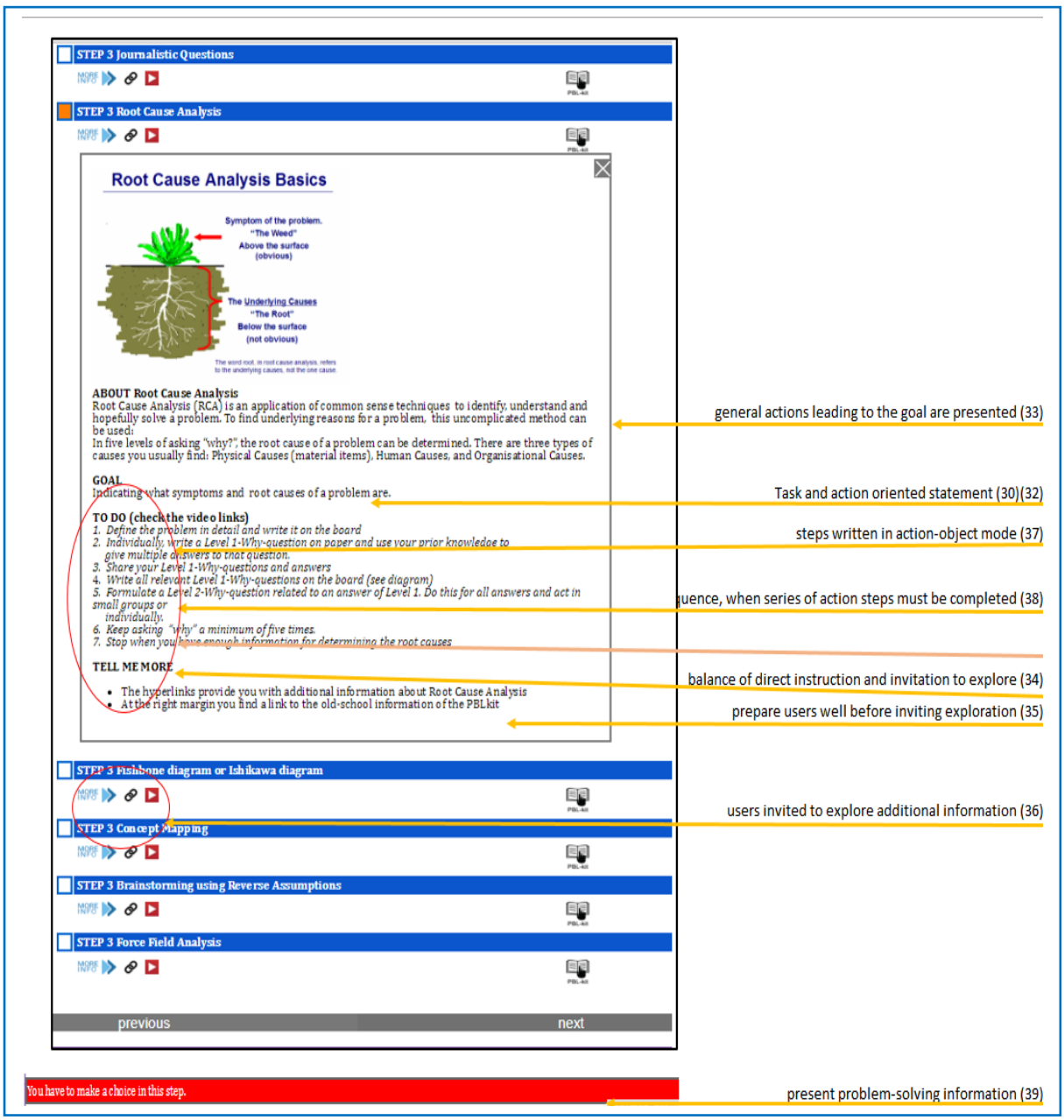


Figure 13. Application of guidelines Four Components model in UI of a MoA.

4 Developing and testing of prototypes

4.1 Introduction

The design guidelines derived from the analysis in chapter two and the design theories in chapter three gave direction to the design of Prototype A of step three of the web-based PBL-tool. Strengths and weaknesses of this design were listed after the first formative evaluation of the design was executed by students of the program. Research was done to implement effective solutions for the weaknesses, and subsequently adjustments to these elements of the design were implemented in Prototype B. Formative evaluation by students was repeated for Prototype B and additionally, experts in the field of PBL and HCI tested this prototype. In the following sections the iterative process of design and testing, also known as Rapid Prototyping (Tripp & Bichelmeyer; as cited in Smith and Ragan, 2005), is described.

4.2 Development of prototype A

The analysis of the architecture of the PBL-process as shown in Figure 6 and the design of the decision-making process shown in Figure 7 (Chapter 2) formed the foundation for developing the information architecture of the web-based PBL-tool. After designing the architecture, the 23 design guidelines that were drawn up as conclusions from the preliminary investigation were integrated in this first prototype, as well as the 39 design guidelines that emerged from the instructional design theories that were discussed in chapter three. The aforementioned process led to a prototype of which the main window is shown in Figure 14.

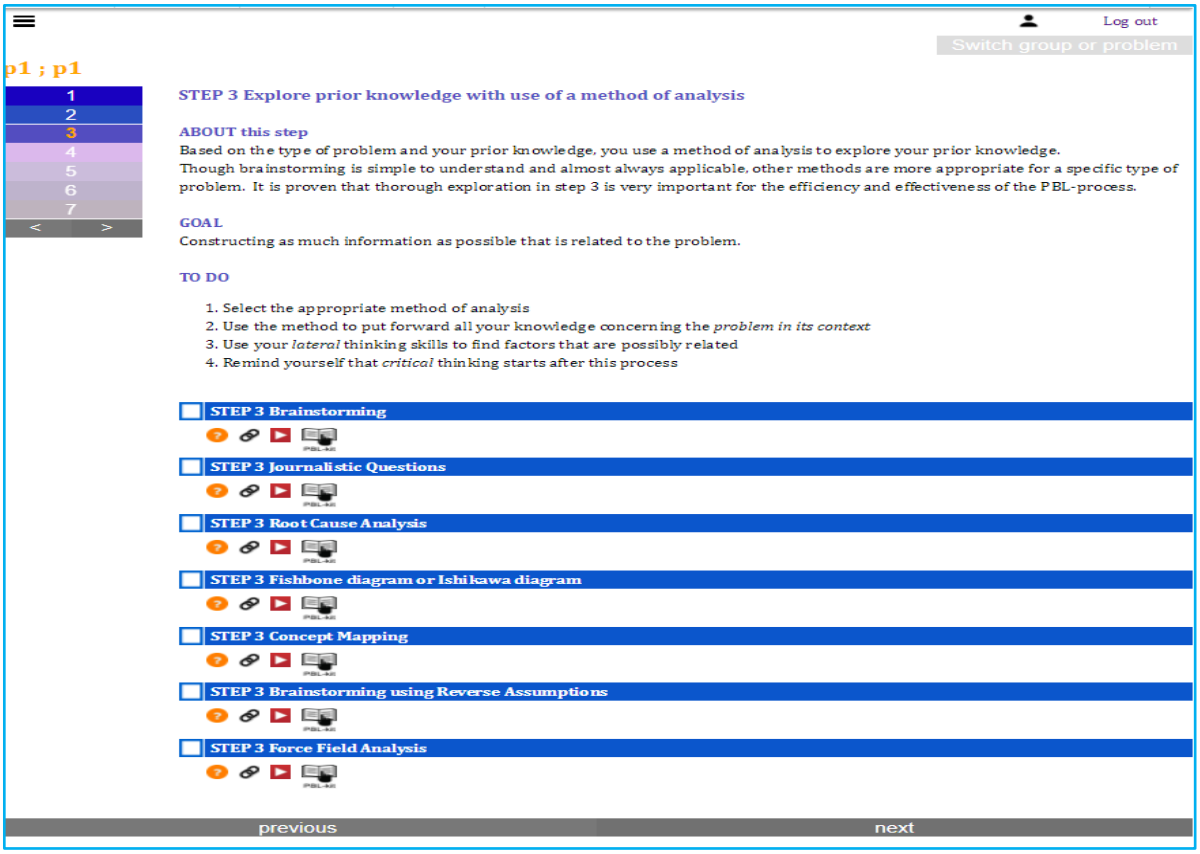


Figure 14. Display of main window of step three.

4.3 Testing Prototype A

4.3.1 Method

In the first testing round, it was emphasized to test the usability of the web-based PBL-tool on the concepts listed in the Expert Review Checklist of Travis (2014): navigation & information architecture, page layout & visual design and task orientation. Twelve experienced PBL-participants received minimum instruction and were asked to use the tool during two PBL-tutorials. Derived from the checklist of Travis (2014), a set of eighteen statements concerning the concepts listed above was leading in the semi-structured interviews researcher had with ten participants (see Appendix D). To check outcomes on the strength and weakness of the design that emerged from the interviews, a panel of three participants discussed and listed the outcomes per concept under supervision of researcher.

In order to implement effective solutions for the weaknesses that participants formulated, relevant additional literature was compared and combined with the design guidelines that were applied in the web-based PBL-tool.

Because expertise in the use of the different MoAs could influence the selection of a MoA, the ten participants were asked to answer three questions concerning (knowledge of the) application of the different MoAs, before they started the PBL-tutorials (see Appendix E).

4.3.2 Results

Participants were in general positive about the design and use of the web-based PBL-tool. Both strong and weak points that participants experienced in using the web-based PBL-tool are listed per discussed concept in Table 8.

Table 8: Overview of strength and weaknesses indicated by testers of Prototype A

Conclusions after interviews with testers Prototype A	
Weak	Strong
Task orientation	
1. The function of the question mark button was not clear. Students did not expect to find in-depth information. 2. The icon designed to direct the students to the online PDF-version of the old-school PBL-kit was used by students to find in-depth information about a MoA. Indicated cause: they didn't expect to find it behind the question-mark button and were attracted to the familiar PBL-kit. 3. Students explored three out of seven MoAs: the same ones they were used to apply during PBL-tutorials. The causes they mention are: . The ease of using MoAs they always used (first semester first year practice) . Lack of training in PBL in general and using MoAs specifically . Lack of time to explore and try MoAs they are not familiar with . Tutors don't stimulate students to use other MoAs	7. The number of screens per task was limited and little scrolling and clicking is needed to know what to do.
Navigation & Information Architecture	
4. Navigation to pages via the visible buttons of hyperlinks, was not clear. Cause: suggestion to use the hyperlinks was hidden behind the question-mark icon	8. There are little menu levels and when you know what to do, it is easy to skip the information, because titles are clearly stated. 9. The structure of the windows is simple and has no unnecessary levels 10. The windows can be viewed without scrolling and they close automatically when you move to the next step. 11. Instructions and prompts of the MoAs look the same and appear on the same place in different windows.
Page Layout & Visual Design	
5. It was not obvious that one should click on the icons displayed	12. The titles and colours used are clear and recognisable for the students

6. It was unclear that one should check the box of the selected MoA before proceeding to next step.	13. A very strong point is that the titles of all MoAs are presented in one window, so selecting one is easy. 14. The layout of the main window and the pages of the MoAs was consistent, and all icons were familiar.

The result from the questionnaire about knowledge of the MoAs revealed that all participants indicated to never have used other MoAs than Brainstorming, Journalistic Questions, and Mind mapping.
The two items of the questionnaire that tested their knowledge about the most appropriate MoA to apply in a specific problem, showed that one participant answered correctly and nine participants could not indicate the most appropriate MoA in both cases.
In the panel discussion, participants indicated that in addition to the lack of clarity in how to use the tool, the fact that they used the same three MoAs for almost two years, and their lack of knowledge about the MoAs has had an influence on the tendency to explore other MoAs.

4.4 Development of Prototype B

4.4.1 Introduction

In order to improve the design, literature was studied to find convenient solutions for the six weaknesses indicated by student users (see Table 8). However, a complicating factor in drawing conclusions for task orientation in step three is that the inventory of the expertise in applying the different MoAs revealed users' lack of knowledge for selecting an appropriate MoA. It was therefore decided to explore possibilities for integration of an extra feature into the design, which could evoke users to select a MoA they are not familiar with. In the next sections the re-design of elements and the additional design-based on the testing outcomes is described.

4.4.2 Re-design of elements

Replace the question-mark icon

Although there is not yet universal recognition of icons used in UI (Alluri, 2012), the convention is that the question mark icon offers information to the user that is needed when she has a question, and the icon is in general seen as being analogous to a link to the entire systems' operating manual. When the user is searching for additional information, but doesn't have a question, the system offers mostly an "i" icon, and users mostly expect no more than the instruction for the topic next to this icon (Hamborg et al., 2004).

Another design feature that could help with attracting the user to the appropriate icon, is providing additional explanatory text close to that icon (Clark & Mayer, 2011). Hence, changing the question mark icon to an "i" icon with additional information could be an effective adjustment. However, to maintain consistency for content (Blair-Early & Zender, 2008) and to be as brief as possible (van der Meij, 2007), the proposed design is an icon with integrated additional explanatory text. This design is in alignment with the icons for hyperlinks and YouTube clips used in the web-based PBL-tool.

Adjustment in the UI design: replacing the question mark icon by an icon with integrated text “more info” (see Figure 15)

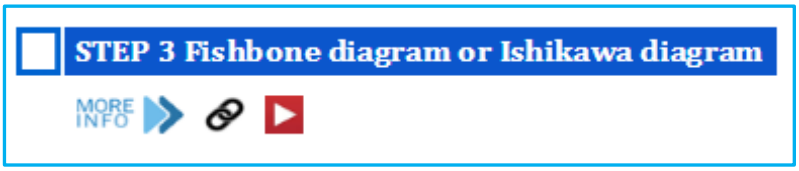


Figure 15. Replacement of [?] by icon [MORE INFO] for each MoA.

Decrease the use of the PBL-kit icon

The PBL-kit icon was often used by students for two reasons: misunderstanding of the use of the question mark icon, and the familiarity with the word “PBL-kit”. Students knew what to expect when clicking on this icon, which was prominently displayed in the row of icons on the left margin of the UI.

The UI offers this icon as a service to experienced students that indicated to prefer to use the old school PBL-kit, and directs them to a PDF version of this kit. However, it has no added value to both novice students and students that are willing to use the web-based PBL-tool. In this case, the design guideline of placing all icons displayed at each MoA in consistent proximity to each other (Blair-Early & Zender, 2008) implies that moving the PBL-icon away from the row of icons will make it more difficult to find and consequently use.

Adjustment in the UI design: transfer the PBL-icon from the row of icons towards the right margin of the UI (see Figure 16).

Figure 16. Display of transfer icon PBL-kit to right margin of UI

Make it more obvious that the icons are hyperlinks

In the initial design, the reasoned choice was made to create buttons for hyperlinks to webpages and YouTube clips with use of familiar interface conventions. Since buttons are obviously clickable, there was no reason to give more signals to the user to indicate that the buttons are hyperlinks (Nielsen, 2004). To make it clear to the user, change of shape and change of background colour are ways to indicate that the buttons are clickable, and an often used and familiar interface feature that gives the user visual feedback is the change of the cursor shape from default pointer to hand-cursor (Li, 2017).

> Adjustment in the design: when hovering over the icons with hyperlinks, the default pointer cursor will change into a hand-cursor to indicate that the icon is clickable.

Make selecting a MoA easier for the user

Selecting a MoA is necessary to proceed to the next step, and students indicated that they did click on the blue bar of the MoA, but did not understand that they specifically had to check the box at the left side of the blue bar.

> Adjustment in the design: expand the area for selecting the MoA from only the check box to the full length of the blue bar.

4.4.3 Additional element

Stimulate exploration of all Methods of Analysis

It is assumed that the desired selection of not frequently consulted MoAs is already improved by the modifications “replace the question-mark button” and “transfer the PBL-icon” that are discussed above. Additionally, to evoke exploration of the MoAs, the UI element of hovering is included in the design: when the user moves the mouse over the blue bar of a specific MoA, a pop-up appears containing concise information about the MoA. This feature, known as a tooltip, appears as long as the mouse is on the blue bar, disappears when the mouse leaves it, and is used to support users in understanding content and tasks without the need to click for that support (Burghardt, Schneidermeier, & Wolff, 2013).

> Adjustment in the UI design: integrating a pop-up for each MoA, while hovering above the blue bar (see Figure 17)

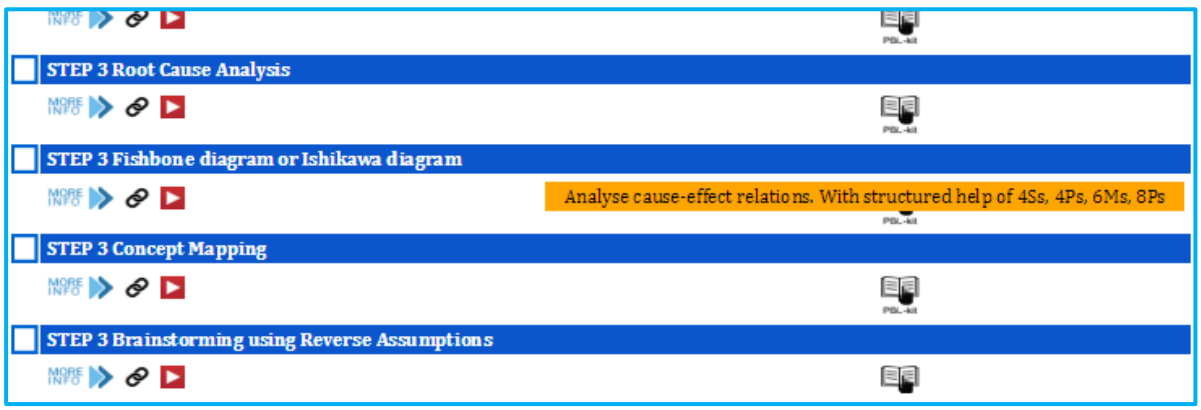


Figure 17. Display of pop-up while hovering over the blue title bar of a MoA.

4.5 Testing Prototype B

4.5.1 Introduction

After adjustments resulting from the first-round test were implemented, prototype B (Bleijenburg & Mennink, 2016) of the web-based PBL-tool was evaluated by four experts (see Appendix F) with the use of the Expert Review Checklist (Travis, 2014).
After the students used the tool during three regular PBL-tutorials, perceived user interface design and perceived functionality of the web-based PBL-tool was evaluated with use of the validated survey of Cho, Cheng, and Lai (2009).
Findings of observations by researcher, including the audio recordings during these PBL-tutorials were evaluated by researcher and tutors involved.
Below, the methods and results concerning testing Prototype B is described. After describing the points of improvements suggested by experts and student-users, the chapter ends with conclusions for design.

4.5.2 Method

The validated Expert Review Checklist of Travis (2014), based on the HCI design guidelines of the International Organization for Standardization (2006) was sent by email to two experts in the field of the educational concept of PBL and two experts in the field of UI.
The experts assessed the tool by scoring statements on the concepts Task Orientation (44 items), Navigation & Information Architecture (21 items), Writing & Content Quality (23 items), and Page Layout & Visual Design (38 items), statements of which a complete list per concept is included in Appendix G. Examples of statements are: “the task sequence parallels the users’ work processes”, “the navigation system is broad and shallow, rather than deep”, “there is a good balance between information density and white space”. A score of 1 indicated that all requirements of the heuristic were met, a score of 0 on an item indicated that some changes were necessary and a −1 indicated the item was not successful implemented. When a statement was found not applicable to the website, the experts were asked to leave the score box open. An additional column was added to give the expert room for comment per statement. The data per respondent were automatically processed, and a numerical rating for compliance with design guidelines was displayed in a table and a radar chart (see Appendix H).

To gather data of the end-user concerning user satisfaction (USat) and perceived usefulness (PU), the web-based PBL-tool was evaluated with use of the standardised survey of Cho, Cheng, and Lai (2009). Both factors are predictors for continued usage intention (CUI), a construct that also will be evaluated. The survey distinguishes two factors that impact PU: perceived user interface design and perceived ease of use. All factors were evaluated to provide specific information for further development of the web-based PBL-tool.
After completion of the PBL tutorials, the online survey with seventeen Likert type items (see Appendix I) was distributed among ten participants that worked with the web-based PBL-tool during PBL-tutorials. The students had to state to which extend they agreed on a statement

by checking a box with “not”, “a little”, “quite”, “indeed”, or they could state that they had no opinion. Data of the respondents were automatically processed and subsequently the described factors were analysed.
Additionally, in three open questions the students were asked to give remarks or suggest improvements for the use of the web-based PBL-tool. The outcomes of the survey were summarized and the suggested improvements were listed.
Furthermore, to provide insight in the actual use of the web-based PBL-tool in step three of the process, audio recordings of three PBL-tutorials were analysed on the use of the web-based PBL-tool. To search for convergence and find information about causes, the analysis combined with observations of researcher during these PBL-tutorials was discussed with the tutors (see Appendix F) of the PBL-tutorials.

4.5.3 Results

Experts Review

Evaluating the overall score of compliance with the guidelines per concept was done by comparing and combining the outcomes of the four Expert Review Checklists, displayed in Appendix H. The results show that compliance with the guidelines of the concept Writing & Content Quality was evaluated with the highest average score of 95%, while the average score of the other three concepts was in the ranch of 80-84% (see Table 9). One HCI experts reviewed the concepts Task Orientation and Page Layout & Visual Design with respectively 61% and 64% compliance with the guidelines. Both PBL experts reviewed the web-based PBL-tool on all concepts with scores not lower than 85%.

Table 9: Summarised scores of compliance with guidelines (by experts)

		Expert 1 (HCI)	*Expert 2 (HCI)*	*Expert 3 (PBL)*	*Expert 4 (PBL)*
Concept	*Average score (%)*	*%*	*%*	*%*	*%*
Task Orientation	80	61	84	85	89
Navigation & IA	84	79	79	92	85
Writing & Content Quality	95	93	98	95	93
Page Layout & Visual Design	81	64	85	89	87

Experts comments and suggestions

The comments and recommendations per concept made by the experts in the Expert Review Checklist (Travis, 2014) provided the following information:

Task orientation

1. It was hard to understand the workflow.
2. It was unexpected that the selection of a certain method of analysis did not direct the user to a page with the procedural information after clicking the next-button.

Navigation and Information Architecture

3. There is no visible change when the mouse points at something clickable (excluding cursor changes).
4. The site map on the top left has no hover with additional info.
5. Paragraphs are hidden. You need to open and close each block to see what is inside.
6. When you want to see what happens when you select different MoAs you have to select them one by one.
7. A privacy policy is missing

Writing and Content Quality

8. Length of text is an issue. Paragraphs can be shorter and easier to scan by the user.

Page Layout and Visual Design

9. The site is not pleasant to look at. The site looks like a prototype.
10. The site could not be a production site because its design is unfinished.
11. Buttons and links don't show that they have been clicked.

Furthermore, the HCI expert that had no knowledge of the educational concept of Problem-based Learning expected with first time use of the web-based PBL-tool, the need for more guidance than the tool provides. This expert assumed that understanding the PBL-process would be a condition for using the tool successfully.

Online survey among expert-students after use of tool in three regular PBL-tutorials

The first main factor analysed from the outcomes of the survey (see Appendix J) among expert PBL-student users was USat, of which two statements were scored by the student-users. Both statements "Using the PBL-tool would give me a better opportunity to explore the methods of analysis" and "Using the PBL-tool would give me a sense of self-control on the learning pace" were positively scored by 83% of the respondents and 15% of the respondents indicated not to agree with both statements.

The second main factor under investigation was PU. Analysis of the data showed that 62.5% of the students scored positively with "quite" or "indeed". Students scored the statement "the use of the web-based PBL-tool enabled me to learn more quickly about the MoAs" most positively, and "no" was not scored for this statement.

As stated in the method section, improvements for PU can be found in improving perceived user interface design (PUID) and perceived ease of use (PEOU). Therefore, the scores for the statements related to these factors were also analysed: the outcomes for PUID showed high scores on the statements "The instruction provided with the methods of analysis is clear" and "The layout has a good structure." and had no significant low scores. In the factor of PEOU, a low score was given for the statement "the use of the web-based PBL-tool is simple" while all students agreed on the statement that the information given in the PBL-tool was easy to comprehend. The three items of the questionnaire that were directly related to their continued usage intention, showed that 67% of the students stated to use the web-based PBL-tool in the future, and intend to increase the use of the web-based PBL-tool.

Expert student-users suggestions

The students made a remark about the fact that as expert-students, they were accustomed to using the hard-copy PBL-kit and Blue Card and experienced the use of a new instrument, such as the web-based PBL-tool as time consuming. However, students stated that the web-based PBL-tool is thought of as useful for novice students in PBL-tutorials, because it would help them understand the concept of PBL more easily than the current learning materials. Mandatory use of the web-based PBL-tool by novice users was recommended. Further remarks that came forward from the open questions, will be summarised in the following sections.

Task orientation

The steps to take after selecting a MoA were not visible instantly, and clicking a button to find these steps was experienced as superfluous.

Navigation and Information Architecture

Students did not find a hyperlink to the problem text that had to be discussed, and stated that is was disturbing to switch from the website with the problem text to the website with the tool.

Writing and Content Quality

Furthermore they suggested to shorten the sentences used for explaining the MoAs. A comment on the video-examples was given by stating that because of time-limits of a PBL-tutorial, watching the explanatory videos is perceived as too time-consuming.

Page Layout and Visual Design

Students suggested to design a more attractive and more colourful web-based PBL-tool.

Outcomes discussion with tutors based on observations and audio recordings

Similarities in the use of the PBL tool occurred in all three observed groups, and therefore the discussion in relation to this observed use of the tool was conducted with the joint tutors of these groups (see Appendix F). A summary of the behaviour is given in the left column of Table 10 (see below). Subsequently the remarks made by the tutors is described in the right column of the table.

Table 10: Use of web-based PBL-tool during observed and audio-recorded PBL-tutorials

	Observed behaviour	*Comment of tutors*
1	Students tried their best to select a MoA they are not familiar with in a (inconvenient behaviour according to observer)	This particular behaviour was incited by tutors before starting the PBL-tutorial.
2	Students had to read quite a long time before they knew how to proceed with the MoA they selected	Two factors are indicated for this issue: both the web-based PBL-tool as the MoA they selected are relatively new to the students. Tutors expect that these experienced students need approximately little time to get accustomed to the web-based PBL-tool and indicate

		that the web-based PBL-tool would eventually accelerate the procedure in step three. Tutors acknowledge that tutors could improve own expertise concerning the use of appropriate MoAs.
3	In the group, one student was reading out loud the *conceptual information* of a MoA she thinks is appropriate	Students feel the pressure of the limited time they have, and tutors recognize the behaviour as a step towards making a choice. The same behaviour occurred in PBL tutorials where the hard copy PBL-kit and Blue Card were used. Tutors suggested to integrate reading out loud the conceptual information in the instruction of step three.
4	Tutors did help students with selecting MoA by explaining in what situations to use it and what characteristics the problem has.	Tutors indicated that presented problems are not always described in a way that students can recognize the situation, and subsequently select an appropriate MoA.
5	One student started to read out loud to explain the *procedure* of the MoA	See 3. Except: tutors were not in favour of adding an instruction in the web-based PBL-tool for reading out loud this type of information.
6	Students discussed about prior knowledge as an indicator for using a MoA	Tutors indicated that brainstorming is the MoA that is often used and this method is known for using when participants don't have prior knowledge, so they suggest this would be their first indicator to think of. Adding "level of prior knowledge" as an indicator is not a necessary adjustment, according to the tutors.
7	Students did not often consult information via a hyperlink.	Tutors thought that it is seen as too time consuming to consult other websites, and again they suggested to integrate a training for PBL with time to explore the web-based PBL-tool.
8	Students did not consult information via a video-clip	See 8, and additionally tutors mentioned that it is not desirable to watch a clip individually in a PBL tutorial, since there is mostly sound involved and that would disturb the group process.
9	After selecting a MoA, students needed a lot of time (between 40 and 50 minutes) to round off step three of the PBL-process	Tutors indicated that step three is always time consuming (mostly 30-45 minutes), and that is not experienced as problematic. Tutors assumed that this was not caused by the information (conceptual or procedural) in the web-based PBL-tool. Tutors expected that after using a specific MoA for more than five times, the duration of step three would significantly decrease when the web-based PBL-tool would be used.
10	The web-based PBL-tool was often consulted both for conceptual as for procedural information	Tutors agreed, and stated that it was more consulted than the hard copy PBL-kit in previous PBL tutorials. Reasons they gave is that students were novice users of the web-based PBL-tool and were using a MoA they were not familiar with. Tutors suggested to work with the web-based PBL-tool for two modules and monitor the times and duration of consultation.

5 Conclusion

Based on results from this study, findings with concern to the main research question "How to design a web-based tool that supports the analysis phase of PBL in order to promote students' selection of an appropriate method" and subsequently the sub-questions of this design-based research are discussed. The chapter concludes with a description of the limitations of the study.

5.1 Findings on the main research question

This design-based research aimed to construct a supportive web-based tool for step three of the PBL-process that replaced the existing hard copy learning materials, and promoted both exploration of MoAs and selection of an appropriate MoA for the problem at hand.
The research was structured according to the instructional design model of Plomp (Verhagen, 2000), and the for computer-based instruction valuable iterative cycles of formative testing and improving the design, known as Rapid Prototyping. The structure was perceived as an appropriate way to design, develop and evaluate the web-based PBL-tool with contributions of all stakeholders during the design process.
The questionnaire items related to continued usage intention, answered by expert student-users after testing Prototype B, showed that 67% of the students stated to use the web-based PBL-tool in the future, and that they intend to increase the use of it.
In answer to the main research question "How to design a web-based tool that supports the analysis phase of PBL in order to promote students' selection of an appropriate method of analysis, it could be stated that the for this study final product Prototype B forms a firm base for future design of the web-based PBL-tool as an instrument that is perceived as useful for exploring and selecting MoAs in step three of the PBL-process.

5.2 Findings on sub-questions

5.2.1 Findings on sub-question 1

To answer the first sub-question "How to apply guidelines for user interface design in designing the web-based PBL-tool?" this research focused on literature on both instructional design theories and HCI theories. Conclusions from this study were used to draw up a list of guidelines for the initial design of the web-based PBL-tool. The information architecture of this initial design was determined by analysis of the architecture of the existing PBL process, the decision making process, and finally the comprehensive task-analysis of GOMS (see section 2.3).

Application of the design guidelines for the UI took place in an iterative process called Rapid Prototyping (as discussed in sections 1.4 and 4.1) where development and formative evaluation of the web-based PBL-tool took place firstly by designers, student-users (Prototype A), and subsequently by student-users, HCI experts, PBL experts.

The web-based PBL-tool was designed in alignment with the discussed UI guidelines (see section 3.3 and 3.4) and tested by researcher and web-designer before Prototype A was presented to the first group of expert student-users. Evaluation of the web-based PBL-tool considered the concepts Task orientation, Navigation & Information Architecture, Page Layout & Visual Design, and Writing & Content Quality.

The first round of testing with users revealed two significant errors in the design: clicking the question-mark button below a MoA was hardly done, while instructions on how to proceed with step three were placed behind this button, and secondly: hyperlinks to conceptual information of the MoAs were incidentally used, while the icon of the PBL-kit that directed users to a PDF version of the old-school PBL kit, was often used to find this information. Testers were positive about menu levels, structure of a window, and uniform design of windows and labels.
HCI literature provided information to find convenient solutions for the errors in the design and Prototype B was developed by replacing, redesigning, and transferring UI elements (see section 4.4).

Testing Prototype B by student users showed that modification of the design was successful: they consulted as well conceptual as procedural information presented after recognizing and clicking the appropriate button. They also checked hyperlinks that directed them to in-depth information of a MoA. Nevertheless, some suggestions for improvement of the site were made by student-users, mostly related to efficiency in the use of the site. The suggestions concerned

Task Orientation: a new window with procedural information should open automatically after selecting a MoA;
Information Architecture: integrating the text of the problem to discuss would be useful;
Writing & Content Quality: the length of text in window with procedural information should be shortened, and watching explanatory videos is perceived as time-consuming;
Visual Design: the design should be more attractive.

Except for the issue of the information architecture, the HCI experts had similar remarks after testing Prototype B, and assessed the visual design as “impression that it is unfinished”. Tutors of the observed PBL groups mentioned that time-consuming elements are considered a problem that would eventually disappear after practice in using the web-based PBL-tool.
It can be concluded that application of design guidelines is an ongoing process of developing and testing, and that aforementioned issues keep inciting researcher to investigate and test improvements for the web-based PBL-tool.

5.2.2 Findings on sub-question 2

The constructs User Satisfaction (USat) and Perceived Usefulness (PU) of the validated survey of Cho, Cheng, and Lai (2009) were used as reliable indicators for evaluating the sub-question “To what extent do users indicate that the design supports the selection of an appropriate

method of analysis?". The outcomes of the survey (see Appendix J) among expert student-users after they tested Prototype B several times during their regular PBL tutorials, showed that 83% of the respondents indicated to perceive better opportunities to explore the MoAs when using the web-based PBL-tool and to feel in control over the learning pace (USat), while the other participants responded with a negative score. For the factor PU, 65% scored positively, while negative scores were not given. The statement "the use of the web-based PBL-tool enabled me to learn more quickly about the MoAs" was scored most positively, while the statement "it improved the quality of my learning environment" received the lowest score.

To provide more insight in the PU, the perceived ease of use and perceived user interface design (PUID) were analysed, since they (indirectly) influence PU (see section 4.5.3). After analysing the scores for these two constructs, it seems reasonable to firstly investigate improvements in ease of use: though students indicate that the information given in the web-based PBL-tool was easy to comprehend, most students perceived the overall use of the web-based PBL-tool as not simple.

Based on the scores, the conclusion can be made that investment in user interface design in future design of (a prototype of) the web-based PBL-tool is likely to have a positive influence on perceived usefulness, hence perceived support of the web-based PBL-tool. The overall conclusion is that expert student-users indicated that the design supports exploration of all MoAs, and it is assumed that selection of an appropriate MoA follows from this support.

5.3 Limitations

Students that tested the web-based PBL-tool were experts in PBL, which might have influenced the evaluation of the web-based PBL-tool. Firstly because it was assumed that these students, despite their use of only three, had knowledge of all MoAs presented in the existing learning materials. However, after testing Prototype A, the expert students-users indicated to have no/little knowledge about the MoAs and when to apply a specific one. Additionally, expert student-users value the scaffolding of the PBL process significantly lower than students that are novice in PBL (Otting & Zwaal, 2016), and do not feel the need for guidance in selecting an appropriate method of analysis. The web-based PBL-tool and exploring the conceptual information of the MoAs was perceived as time-consuming, which could have influenced their perceived usefulness of the web-based PBL-tool.

Furthermore, a group of ten expert-students of a small scale program (total amount of 73 students) participated in the process of testing the prototypes. Due to the duration of this research, three participants left the program of Stenden IBA and did not submit the questionnaire that evaluated Prototype B. Though the use of this prototype is also evaluated

by observations of researcher during three PBL-tutorials and discussion of the findings with the participating tutors, the sample size could impact the reliability of the outcomes. Generalization of the outcomes of this study is limited, because of reasons mentioned above, and additionally the factor that testing the web-based PBL-tool was done in an educational program that focused solely on problems associated with business administration.

6 Discussion and recommendations

6.1 Implementation of the web-based PBL-tool in program of Stenden University

In this study, the assumption was made that presenting all methods in one window on the website would invite students to explore all MoAs and select an appropriate one for the problem at hand. Although they stated that more than one MoA could be seen as the appropriate one, evaluation of Prototype B showed that as well student-users as PBL experts confirmed this assumption. However, students indicated that selection of- and subsequently proceeding with a MoA that they were not familiar with was perceived as time consuming, and therefore not beneficial.
In order to decrease the time needed to fulfill step three of the PBL process, tutors advised to draw conclusions for (possible) adjustments in the design, after practicing the use of the web-based PBL-tool during the first semester of the first year. Students suggested to make the use of the web-based PBL-tool compulsory for novice students and subsequently incite them to learn when and how to use a specific MoAs during the first module of their academic year.

At the start of this research, tutors indicated that during PBL-tutorials the main reason for the use of only the first three MoAs described in the PBL-kit was that students were directed to them when analyzing problems in the first year. After testing Prototype A, student-users came forward with another reason: tutors did not incite them to use other MoAs, which was subsequently genuinely confirmed by the tutors involved. The reason they gave was that they had little experience in using other MoAs themselves.
The aforementioned variable “dependence on the directions/expertise of the tutor” was left out of consideration in development of the web-based PBL-tool. Another variable that could have influenced the outcomes of the evaluation is that student-users that tested the web-based PBL-tool were experts in PBL, but “novice students” in using other than the first three MoAs described in their PBL-kit, that was used weekly for approximately two year.
Based on the findings above, it seems meaningful to evaluate usefulness of the web-based PBL-tool after students, and moreover PBL-tutors, followed a compulsory training in using the web-based PBL-tool, hence increase their understanding of (application of) all MoAs, before they apply the web-based PBL-tool as an instrument in their PBL-tutorials.

6.2 User Interface design of the web-based PBL-tool

The design of the web-based PBL-tool used in a collaborative learning setting was complex, since components such as the problem at hand, resources, (individual) prior knowledge of the concepts discussed, the process, and procedures, and skills in collaborative learning are determining the design. Furthermore, the scaffolding tool is supposed to be used on a weekly base to provide users with as well procedural as conceptual information during each PBL tutorial, and comprises the fields of PBL as educational concept, technology in education and Human Computer Interaction/UI. Unfortunately, financial resources were available for this

design research, and as a consequence it was decided to build prototypes on a low cost base, hence a simple visual design that showed whether the tool could take over the function of the PBL kit and blue card.
Evaluation of Prototype B revealed design issues that were mostly related to UI: comments and suggestions for improvement from as well HCI experts as student-users were related to the visual design (VD) and the information architecture (IA) of the web-based PBL-tool. In the course of the research it became clear that this perceived UI design influenced the perception of the usefulness (section 5.2.2), and could therefore have influenced the perceived support of the web-based PBL-tool in selecting an appropriate MoA.
Following from this findings, It seems reasonable to state at this stage of the design research, that financial resources are a prerequisite for solving the UI issues such as integration of the problem text and resources, responsiveness, automatic opening of new windows (IA), and the visual design issues such as attractiveness of the main window, visibility of clicked buttons, and contemporary design of the UI.

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Appendices

The problem is either…	Type of problems and aims	Approach	Notes
A description of a future profession core issue	• Explanation problem > explain and understand underlying theories. • Dilemma problem > formulate and explore opinions • Strategy problem > formulate a strategy (steps, procedures) in practical situations ("What would I do if…").	• The 7 steps: in a first tutorial step 1 to 5, step 6 outside the group, step 7 in the next tutorial	• First report, then start up a problem • Vary the way of reporting (discussion, panel discussion, (poster) presentation etc.) • See PBL KIT
An assignment related to a future profession core issue	• Application task > apply specific prior knowledge to a case • Action task > take specific action	• Adapted 7 steps: in a first tutorial step 1& 2, step 3 outside the group, step 4 in the next tutorial	• Make clear appointments about the way to report (discussion, presentation etc.). • See PBL KIT
THE SEVEN-STEP APPROACH: see for further detailed explanation the Stenden PBL KIT			
What	**How**	**Outcomes**	**Notes**
The starting up of a problem (step 1 to 5) in a first PBL Tutorial			
Step 1 **Exploring problem text and context**	**First of all:** **Step into the professional context described or in the position of the person / professional mentioned.** • Read the text thoroughly with close reading techniques and explain relevant concepts, each paragraph and the text structure • Paraphrase the text in your own words. • Define the boundaries of the problem. • Determine the core issue and summarise it. • Discuss the core issue: share possible experiences or recognition	• Everyone understands the complete text and the context, contents and core issue are clear to everyone. • There is an agreement about what is beyond the scope of the problem • You feel involved in the professional situation	• You approach the problem as if you were a professional. • Explain text elements, even if you think they are already clear. Don't forget to clarify each paragraph. • Think about disciplines (e.g. Management, Marketing, Sociology, Psychology etc.) that could provide further insight or further detail on the problem. • Paraphrase and summary are not the same and also differ from interpretations. • Apply critical thinking skills
Step 2 **Defining the problem**	• Determine the type of problem (see above). • Define, in specific terms, the core of the problem. • Formulate a question that involves the core. • Write the question on the board.	There should be an agreed view about: • The type of problem • The question that should be dealt with.	• Use the summary (step 1) as starting point for step 2
Step 3 **Analysing the problem & Inventorying the analysis**	Choose a method of analysis 1. Brainstorm (preferably year 1 only) 2. Journalistic Question (preferable year 1 only) 3. Mind mapping 4. Fishbone diagram 5. Brainstorm using reverse assumptions 6. Force Field Analysis (year 2) 7. (Root Cause method) • Explore and use prior knowledge to formulate ideas, questions, hypothesis, explanations & relations. • Use the board to organise all prior knowledge.	• An overview of all prior knowledge and possible explanations, ideas, hypothesis, questions in relation to the core issue.	• Don't only mention the terms and concepts; also explain the relationship with the definition of the problem. • Mention your sources from which you got the prior knowledge. • Follow all the steps for the chosen method of analysis. **Using words from the presented text is not exploring your own knowledge**

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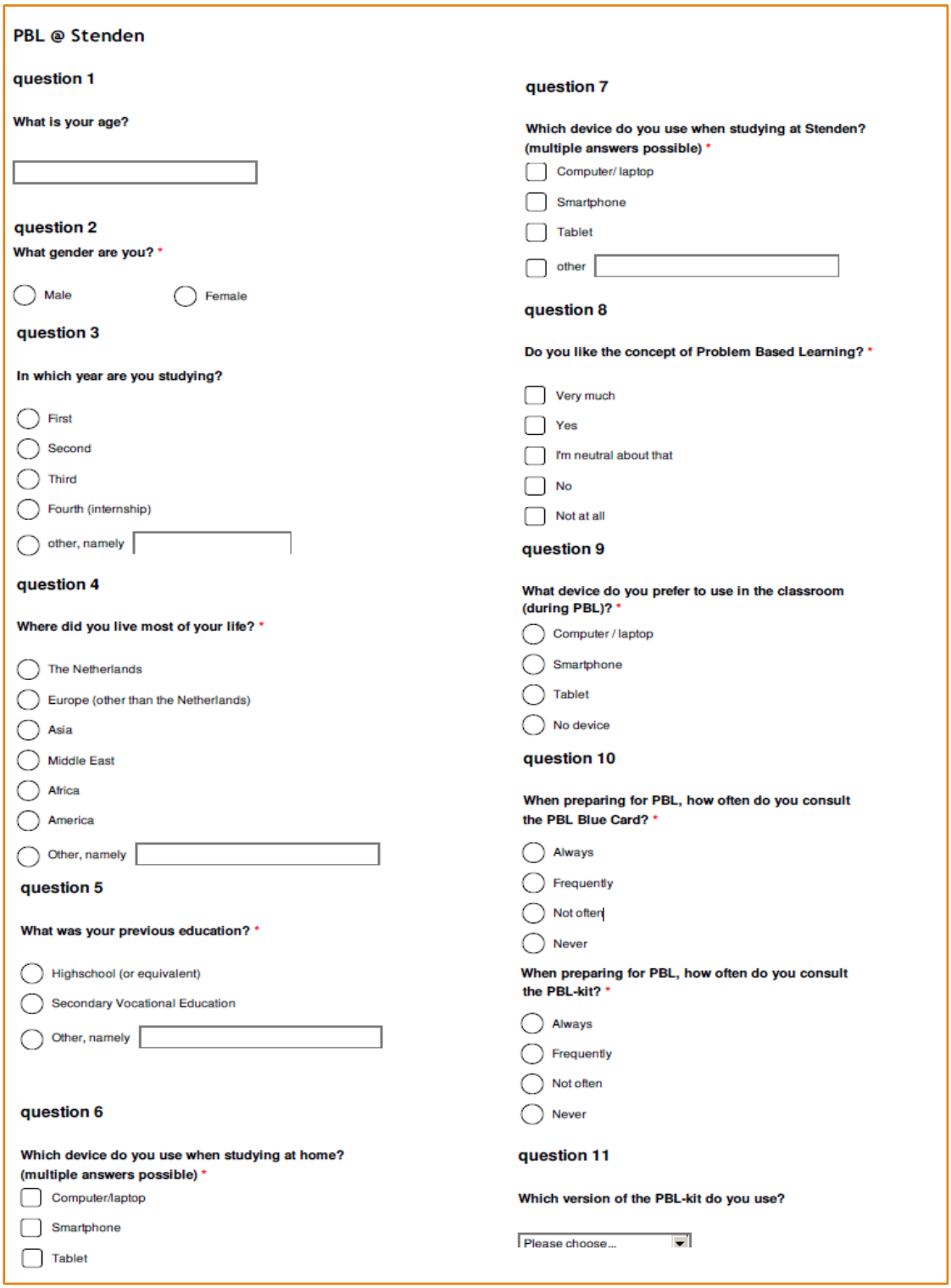
Appendix B: Questionnaire Preliminary Research

Participants: Students of the program IBA at Stenden University of Applied science (N=39)



PBL @ Stenden

question 1

What is your age?

question 2

What gender are you? *

- Male
- Female

question 3

In which year are you studying?

- First
- Second
- Third
- Fourth (internship)
- other, namely

question 4

Where did you live most of your life? *

- The Netherlands
- Europe (other than the Netherlands)
- Asia
- Middle East
- Africa
- America
- Other, namely

question 5

What was your previous education? *

- Highschool (or equivalent)
- Secondary Vocational Education
- Other, namely

question 6

Which device do you use when studying at home? (multiple answers possible) *

- Computer/laptop
- Smartphone
- Tablet

question 7

Which device do you use when studying at Stenden? (multiple answers possible) *

- Computer/ laptop
- Smartphone
- Tablet
- other

question 8

Do you like the concept of Problem Based Learning? *

- Very much
- Yes
- I'm neutral about that
- No
- Not at all

question 9

What device do you prefer to use in the classroom (during PBL)? *

- Computer / laptop
- Smartphone
- Tablet
- No device

question 10

When preparing for PBL, how often do you consult the PBL Blue Card? *

- Always
- Frequently
- Not often
- Never

When preparing for PBL, how often do you consult the PBL-kit? *

- Always
- Frequently
- Not often
- Never

question 11

Which version of the PBL-kit do you use?

Please choose...

Continued on following page

Continued from previous page

question 12; The first part of the question is about the BLUE CARD. The second part of the question is about the PBL KIT

Do you consult the PBL Blue Card in the following steps? *

	never	not often	frequently	always
Step 1 Explore text and context	◯	◯	◯	◯
Step 2 Define the problem	◯	◯	◯	◯
Step 3 Analyse the problem	◯	◯	◯	◯
Step 4 Structure outcomes of step 3	◯	◯	◯	◯
Step 5 Formulate learning goals	◯	◯	◯	◯
Step 7 Discuss and report findings	◯	◯	◯	◯

Do you consult the PBL-kit in the following steps? *

	never	not often	frequently	always
Step 1 Explore text and context	◯	◯	◯	◯
Step 2 Define the problem	◯	◯	◯	◯
Step 3 Analyse the problem	◯	◯	◯	◯
Step 4 Structure outcomes of step 3	◯	◯	◯	◯
Step 5 Formulate learning goals	◯	◯	◯	◯
Step 7 Discuss and report findings	◯	◯	◯	◯

Continued on following page

Continued from previous page

question 13

Replacement of the PBL Blue Card by an online tool is according to you *

- ◯ Not a good idea
- ◯ Worth trying
- ◯ A good idea

Do you want the PBL-kit transferred to web-based information? *

- ◯ No, I stick to the hard copy PBL-kit
- ◯ Maybe, but I like the hard copy PBL-kit
- ◯ Yes, immediately
- ◯ I don't know

Do you think you will use a web-based tool more often than you use the PBL kit?

- ◯ yes
- ◯ no

question 14

What do you think is most important when Stenden develops a digital PBL-tool? *

- The tool must be accessible at all places
- Easy to use on smartphone
- Integration of videoclips that explain a certain step or method
- The tool helps in making choices
- Easy access to in-depth information (like in PBL-kit)
- Integration of a Help-button

» **Redirection to final page of Enquêtes Maken**

Appendix C: Principles and heuristics of Minimalist Design Strategies (Van der Meij and Caroll, 1995)

MINIMALIST DESIGN PRINCIPLES AND HEURISTICS

Principle		Heuristic	
1	Choose an action-oriented approach	1.1	Provide an immediate opportunity to act
		1.2	Encourage and support exploration and innovation
		1.3	Respect the integrity of the user's activity
2	Anchor the tool in the task domain	2.1	Select or design instructional activities that are real tasks
		2.2	The components of the instruction should reflect the task structure
3	Support error recognition and recovery	3.1	Prevent mistakes whenever possible
		3.2	Provide error information when actions are error-prone or correction difficult
		3.3	Provide error information that supports detection, diagnosis and recovery
		3.4	Provide on-the-spot error information
4	Support reading to do, study and locate	4.1	Be brief; don't spell everything out
		4.2	Provide closure for chapters

Appendix D: Questions after testing Prototype A of web-based PBL-tool

(Base for semi-structured interviews and subsequent panel discussion)

Participants: 10 students that tested the tool and participated in subsequent semi structured interviews

Questionnaire with items derived from Expert Review Checklist (Travis, 2014)			ttl students: 10	
Participants: 10 students testing Prototype A of web-based PBL-tool			# of N	# of Y
Task Orien-tation	1	The critical path is clear, with no distractions on route	7	3
	2	Information is presented in a simple, natural and logical order	0	10
	3	The number of screens required per task has been minimised	0	10
	4	The site requires minimal scrolling and clicking	0	10
	5	The site correctly anticipates and prompts for the user's probable next activity	7	3
	6	Items can be compared easily when this is necessary for the task	4	6
Navigation & Infor-mation Architect-ure	7	The navigation system is broad and shallow (many items on a menu) rather than deep (many menu levels)	0	10
	8	The site structure is simple, with a clear conceptual model and no unnecessary levels	0	10
	9	The major sections of the site are available from every page (persistent navigation) and there are no dead ends	3	7
	10	Navigation-only pages (such as the home page) can be viewed without scrolling	0	10
	11	If the site spawns new windows, these will not confuse the user (e.g. they are dialog-box sized and can be easily closed)	3	7
	12	Menu instructions, prompts and messages appear on the same place on each screen	0	10
	13	Terminology and conventions (such as link colours) are (approximately) consistent with general web usage	2	8
Page layout and Visual Design	14	The layout of the page helps focus attention on what to do next	2	8
	15	the functionality of buttons and controls is obvious from their labels or from their design	6	4
	16	icons and graphics are standard and/or familiar	0	10
	17	Each page shares a consistent layout	0	10
	18	standard elements are easy to locate (next, page titles etc.)	0	10

Appendix E: Items of questionnaire to test application of Methods of Analysis
Participants: Ten experienced PBL students before testing Prototype A

Q5	What method(s) of analysis do you mostly use in step three?		BS	6
	(more than one answer possible)		JQ	2
			MM	6
			RCA	0
			ID	0
			BSR	0
			FFA	0
				14
Q9	What method of analysis is most applicable when exploring opportunities for change? (correct answer is FFA)		BS	0
			JQ	3
			MM	1
			RCA	1
			FBD	1
			BSR	0
	correct answer		FFA	1
			don't know	3
				10
Q10	What method of analysis is most applicable when analyzing Cause-Effect Relations? (correct answer is FBD= fishbone diagram)		BS	1
			JQ	1
			MM	2
			RCA	2
	correct answer		FBD	1
			CM	0
			BSR	0
			FFA	0
			don't know	3
				10

Legend

BS	= Brainstorming
JQ	= Journalistic Questions
MM	= Mind mapping
RCA	= Root Cause Analysis
FBD	= Fishbone Diagram
BSR	= Brainstorm with Reversed Assumption
FFA	= Force Field Analysis

Appendix F: List of experts and tutors that participated in evaluation of Prototype B

Experts

J. Wester, MSc (Expert 1)	Website architect, web-developer; Wieswies, NL
Drs. A. de Vries (Expert 2)	Adviseur Onderwijskwaliteit ESR; Stenden University, NL
Dr. G. Geitz (Expert 3)	Lector Sustainable Educational Concepts in Higher Education, NHL Stenden, NL
P.P. Vong, MBA (Expert 4)	Lecturer Management Information Systems and Problem-based Learning-tutor; Stenden University, NL

Tutors

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Appendix G: Checkpoints of Expert Review Checklist to test usability guidelines of PBL-tool (Travis, 2014)

List of usability guidelines to check task orientation

1. The site is free from irrelevant, unnecessary and distracting information.
2. Excessive use of scripts, applets, movies, audio files, graphics and images has been avoided.
3. The site avoids unnecessary registration.
4. The critical path (e.g. purchase, subscription) is clear, with no distractions on route.
5. Information is presented in a simple, natural and logical order.
6. The number of screens required per task has been minimised.
7. The site requires minimal scrolling and clicking.
8. The site correctly anticipates and prompts for the user's probable next activity.
9. When graphs are shown, users have access to the actual data (e.g. numeric annotation on bar charts).
10. Activities allocated to the user or the computer take full advantage of the strengths of each (look for actions that can be done automatically by the site, e.g. postcode lookup).
11. Users can complete common tasks quickly.
12. Items can be compared easily when this is necessary for the task (e.g. product comparisons).
13. The task sequence parallels the user's work processes.
14. The site makes the user's work easier and quicker than without the system.
15. The most important and frequently used topics, features and functions are close to the centre of the page, not in the far left or right margins.
16. The user does not need to enter the same information more than once.
17. Important, frequently needed topics and tasks are close to the 'surface' of the web site.
18. Typing (e.g. during purchase) is kept to an absolute minimum, with accelerators ("one-click") for return users.
19. The path for any given task is a reasonable length (2-5 clicks).
20. When there are multiple steps in a task, the site displays all the steps that need to be completed and provides feedback on the user's current position in the workflow.
21. Price is always clearly displayed next to any product.
22. The site's privacy policy is easy to find, especially on pages that ask for personal information, and the policy is simple and clear.
23. Users of the site do not need to remember information from place to place.
24. The use of metaphors is easily understandable by the typical user.
25. Data formats follow appropriate cultural conventions (e.g. miles for UK).
26. Details of the software's internal workings are not exposed to the user.
27. The site caters for users with little prior experience of the web.
28. The site makes it easy for users to explore the site and try out different options before committing themselves.
29. A typical first-time visitor can do the most common tasks without assistance.
30. When they return to the site, users will remember how to carry out the key tasks.
31. The functionality of novel device controls is obvious.
32. On the basket page, there is a highly visible 'Proceed to checkout' button at the top and bottom of the page.
33. Important calls to action, like 'Add to basket', are highly visible.
34. Action buttons (such as "Submit") are always invoked by the user, not automatically invoked by the system when the last field is completed.
35. Command and action items are presented as buttons (not, for example, as hypertext links).
36. If the user is half-way through a transaction and quits, the user can later return to the site and continue from where he left off.
37. When a page presents a lot of information, the user can sort and filter the information.
38. If there is an image on a button or icon, it is relevant to the task.
39. The site prompts the user before automatically logging off the user, and the time out is appropriate.

List continues on following page

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40. Unwanted features (e.g. Flash animations) can be stopped or skipped
41. The site is robust and all the key features work (i.e. there are no JavaScript exceptions, CGI errors or broken links).
42. The site supports novice and expert users by providing different levels of explanation (e.g. in help and error messages).
43. The site allows users to rename objects and actions in the interface (e.g. naming delivery addresses or accounts).
44. The site allows the user to customise operational time parameters (e.g. time until automatic logout).

List of navigation and IA usability guidelines

1. There is a convenient and obvious way to move between related pages and sections and it is easy to return to the home page.
2. The information that users are most likely to need is easy to navigate to from most pages.
3. Navigation choices are ordered in the most logical or task-oriented manner.
4. The navigation system is broad and shallow (many items on a menu) rather than deep (many menu levels).
5. The site structure is simple, with a clear conceptual model and no unnecessary levels.
6. The major sections of the site are available from every page (persistent navigation) and there are no dead ends.
7. Navigation tabs are located at the top of the page, and look like clickable versions of real-world tabs.
8. There is a site map that provides an overview of the site's content.
9. The site map is linked to from every page.
10. The site map provides a concise overview of the site, not a rehash of the main navigation or a list of every single topic.
11. Good navigational feedback is provided (e.g. showing where you are in the site).
12. Category labels accurately describe the information in the category.
13. Links and navigation labels contain the "trigger words" that users will look for to achieve their goal.
14. Terminology and conventions (such as link colours) are (approximately) consistent with general web usage.
15. Links look the same in the different sections of the site.
16. Product pages contain links to similar and complementary products to support cross-selling.
17. The terms used for navigation items and hypertext links are unambiguous and jargon-free.
18. Users can sort and filter catalogue pages (e.g. by listing in price order, or showing 'most popular').
19. There is a visible change when the mouse points at something clickable (excluding cursor changes).
20. Important content can be accessed from more than one link (different users may require different link labels).
21. Navigation-only pages (such as the home page) can be viewed without scrolling.
22. Hypertext links that invoke actions (e.g. downloads, new windows) are clearly distinguished from hypertext links that load another page.
23. The site allows the user to control the pace and sequence of the interaction.
24. There are clearly marked exits on every page allowing the user to bail out of the current task without having to go through an extended dialog.
25. The site does not disable the browser's "Back" button and the "Back" button appears on the browser toolbar on every page.
26. Clicking the back button always takes the user back to the page the user came from.
27. A link to both the basket and checkout is clearly visible on every page.
28. If the site spawns new windows, these will not confuse the user (e.g. they are dialog-box sized and can be easily closed).
29. Menu instructions, prompts and messages appear on the same place on each screen.

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List of writing and content quality usability guidelines

1. The site has compelling and unique content.
2. Text is concise, with no needless instructions or welcome notes.
3. Each content page begins with conclusions or implications and the text is written with an inverted pyramid style.
4. Pages use bulleted and numbered lists in preference to narrative text.
5. Lists are prefaced with a concise introduction (e.g. a word or phrase), helping users appreciate how the items are related to one another.
6. The most important items in a list are placed at the top.
7. Information is organised hierarchically, from the general to the specific, and the organisation is clear and logical.
8. Content has been specifically created for the web (web pages do not comprise repurposed material from print publications such as brochures).
9. Product pages contain the detail necessary to make a purchase, and users can zoom in on product images.
10. Hypertext has been appropriately used to structure content.
11. Sentences are written in the active voice.
12. Pages are quick to scan, with ample headings and sub-headings and short paragraphs.
13. The site uses maps, diagrams, graphs, flow charts and other visuals in preference to wordy blocks of text.
14. Each page is clearly labeled with a descriptive and useful title that makes sense as a bookmark.
15. Links and link titles are descriptive and predictive, and there are no "Click here!" links.
16. The site avoids cute, clever, or cryptic headings.
17. Link names match the title of destination pages, so users will know when they have reached the intended page.
18. Button labels and link labels start with action words.
19. Headings and sub-headings are short, straightforward and descriptive.
20. The words, phrases and concepts used will be familiar to the typical user.
21. Numbered lists start at "1" not at "0".
22. Acronyms and abbreviations are defined when first used.
23. Text links are long enough to be understood, but short enough to minimise wrapping (especially when used as a navigation list).

List of page layout and visual design usability guidelines

1. The screen density is appropriate for the target users and their tasks.
2. The layout helps focus attention on what to do next.
3. On all pages, the most important information (such as frequently used topics, features and functions) is presented on the first screenful of information ("above the fold").
4. The site can be used without scrolling horizontally.
5. Things that are clickable (like buttons) are obviously pressable.
6. Items that aren't clickable do not have characteristics that suggest that they are.
7. The functionality of buttons and controls is obvious from their labels or from their design.
8. Clickable images include redundant text labels (i.e. there is no 'mystery meat' navigation).
9. Hypertext links are easy to identify (e.g. underlined) without needing to 'mine sweep'.
10. Fonts are used consistently.
11. The relationship between controls and their actions is obvious.
12. Icons and graphics are standard and/or intuitive (concrete and familiar).
13. There is a clear visual "starting point" to every page.
14. Each page on the site shares a consistent layout.
15. Pages on the site are formatted for printing, or there is a printer-friendly version.

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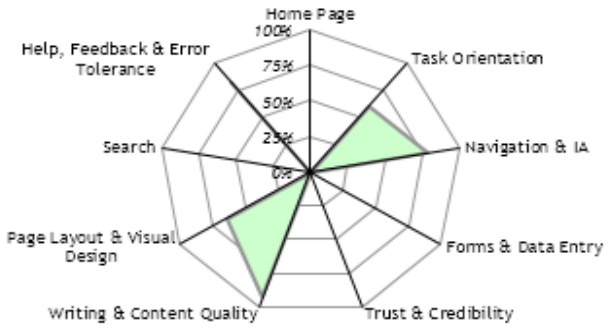
16. Buttons and links show that they have been clicked.
17. GUI components (like radio buttons and check boxes) are used appropriately.
18. Fonts are readable.
19. The site avoids italicised text and uses underlining only for hypertext links.
20. There is a good balance between information density and use of white space.
21. The site is pleasant to look at.
22. Pages are free of "scroll stoppers" (headings or page elements that create the illusion that users have reached the top or bottom of a page when they have not).
23. The site avoids extensive use of upper case text.
24. The site has a consistent, clearly recognisable look and feel that will engage users.
25. Saturated blue is avoided for fine detail (e.g. text, thin lines and symbols).
26. Colour is used to structure and group items on the page.
27. Graphics will not be confused with banner ads.
28. Emboldening is used to emphasise important topic categories.
29. On content pages, line lengths are neither too short (<50 characters per line) nor too long (>100 characters per line) when viewed in a standard browser width window.
30. Pages have been designed to an underlying grid, with items and widgets aligned both horizontally and vertically.
31. Meaningful labels, effective background colours and appropriate use of borders and white space help users identify a set of items as a discrete functional block.
32. The colours work well together and complicated backgrounds are avoided.
33. Individual pages are free of clutter and irrelevant information.
34. Standard elements (such as page titles, site navigation, page navigation, privacy policy etc.) are easy to locate.
35. The organisation's logo is placed in the same location on every page, and clicking the logo returns the user to the most logical page (e.g. the home page).
36. Attention-attracting features (such as animation, bold colours and size differentials) are used sparingly and only where relevant.
37. Icons are visually and conceptually distinct yet still harmonious (clearly part of the same family).
38. Related information and functions are clustered together, and each group can be scanned in a single fixation (5-deg, about 4.4cm diameter circle on screen).

Appendix H: Summaries of results Expert Review Checklist of experts

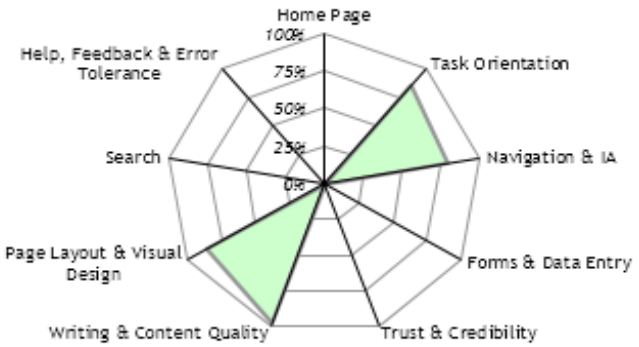
Summary of results — **Review Checkpoints Expert 1 (HCI)**

	Raw score	# Questions	# Answers	Score
Home Page	0	20	0	
Task Orientation	8	44	38	61%
Navigation & IA	14	29	24	79%
Forms & Data Entry	0	23	0	
Trust & Credibility	0	13	0	
Writing & Content Quality	18	23	21	93%
Page Layout & Visual Design	10	38	35	64%
Search	0	20	0	
Help, Feedback & Error Tolerance	0	37	0	
Overall score		247	118	



Summary of results — **Review Checkpoints Expert 2 (HCI)**

	Raw score	# Questions	# Answers	Score
Home Page	0	20	0	
Task Orientation	22	44	32	84%
Navigation & IA	14	29	24	79%
Forms & Data Entry	0	23	0	
Trust & Credibility	0	13	0	
Writing & Content Quality	20	23	21	98%
Page Layout & Visual Design	26	38	37	85%
Search	0	20	0	
Help, Feedback & Error Tolerance	0	37	0	
Overall score		247	114	



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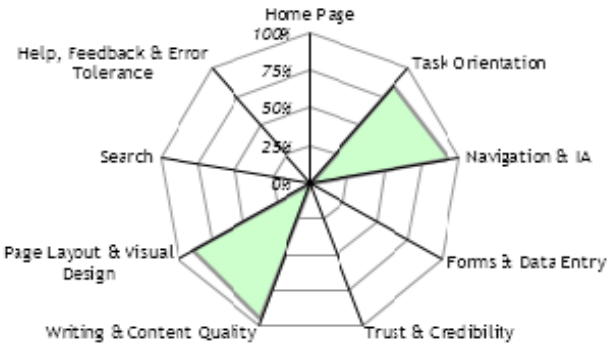
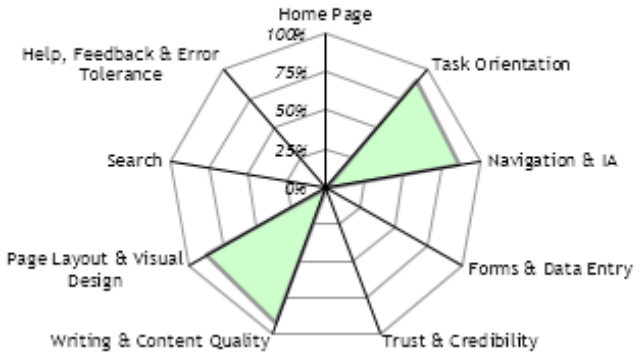
Summary of results — **Review Checkpoints Expert 3 (PBL)**

	Raw score	# Questions	# Answers	Score
Home Page	0	20	0	
Task Orientation	26	44	37	85%
Navigation & IA	20	29	24	92%
Forms & Data Entry	0	23	0	
Trust & Credibility	0	13	0	
Writing & Content Quality	19	23	21	95%
Page Layout & Visual Design	27	38	35	89%
Search	0	20	0	
Help, Feedback & Error Tolerance	0	37	0	
Overall score		247	117	



Summary of results — **Review Checkpoints Expert 4 (PBL)**

	Raw score	# Questions	# Answers	Score
Home Page	0	20	0	
Task Orientation	26	44	33	89%
Navigation & IA	19	29	27	85%
Forms & Data Entry	0	23	0	
Trust & Credibility	0	13	0	
Writing & Content Quality	18	23	21	93%
Page Layout & Visual Design	26	38	35	87%
Search	0	20	0	
Help, Feedback & Error Tolerance	0	37	0	
Overall score		247	116	



Appendix I: Items of Questionnaire Perceived Usefulness, Perceived Ease of Use, User Satisfaction, Continued Usage Intention (Cho et al., 2009)

Participants: 7 student users after testing prototype B during PBL tutorial

Items related to Perceived Usefulness

1. The use of the web-based PBL-tool enabled me to learn more quickly about the methods of analysis
2. The use of the web-based PBL-tool improved the quality of my learning environment
3. The use of the web-based PBL-tool enhanced the effectiveness of my learning in step three
4. The PBL-tool was as a whole useful for me

Items related to Perceived User Interface Design

5. The layout is user-friendly
6. The instruction provided with the methods of analysis is clear
7. The layout has a good structure
8. Overall, the design of the web-based PBL-tool is satisfactory

Items related to Perceived Ease of Use

9. The use of the web-based PBL-tool is simple
10. I have no trouble in using the web-based PBL-tool to perform the task
11. The information given in the PBL-tool is easy to comprehend
12. As a whole, the PBL-tool is easy to use

Items related to User Satisfaction

13. Using the PBL-tool would give me a better opportunity to explore the methods of analysis
14. Using the PBL-tool would give me a sense of self-control on the learning pace

Items related to Continued Usage Intention

15. I intend to use the PBL-tool for selecting a method of analysis
16. I intend to increase my use of the PBL-tool in the future
17. I would use the web-based PBL-tool in the future

Open questions

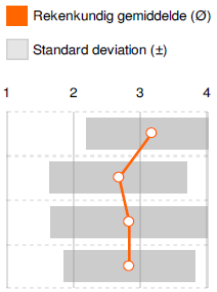
18. Please provide us with suggestions for improvement of the layout:
19. What type of information about the methods of analysis did you miss?
20. What do you suggest to promote/increase the use of the PBL-tool among novice students?

Appendix J: Results of Questionnaire Perceived Usefulness, Perceived User Interface Design, Perceived Ease of Use, User Satisfaction, and Continued Usage Intention (Cho et al., 2009)

Participants: 7 student-users after testing prototype B

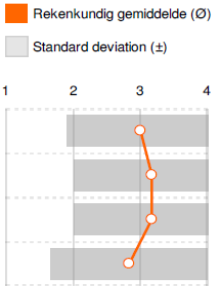
1. The use of the web-based PBL-tool ..... *

	Not (1)		A little (2)		Quite (3)		Indeed (4)		(no opinion) (0)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
enabled me to learn more...	-	-	2x	33,33	1x	16,67	3x	50,00	-	3,17	0,98
improved the quality of m...	1x	16,67	1x	16,67	3x	50,00	1x	16,67	-	2,67	1,03
enhanced the effectivene...	1x	16,67	1x	16,67	2x	33,33	2x	33,33	-	2,83	1,17
was as a whole, useful for...	-	-	3x	50,00	1x	16,67	2x	33,33	-	2,83	0,98



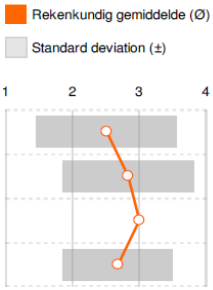
2. Give your opinion about the lay-out of the web-based PBL-tool *

	Not (1)		A little (2)		Quite (3)		Indeed (4)		(no opinion) (0)		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
the lay-out is user-friendly	1x	16,67	-	-	3x	50,00	2x	33,33	-	3,00	1,10
the instruction provided w...	1x	16,67	-	-	2x	33,33	3x	50,00	-	3,17	1,17
the lay-out has a good stru..	1x	16,67	-	-	2x	33,33	3x	50,00	-	3,17	1,17
overall, the design of the ...	1x	16,67	1x	16,67	2x	33,33	2x	33,33	-	2,83	1,17



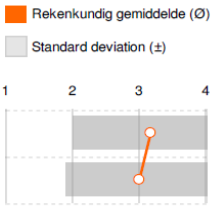
3. What is your opinion about the use of the web-based PBL-tool? *

	Not (1)		A little (2)		Quite (3)		Indeed (4)		(no opinion) (0)		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
The use of the PBL-tool is...	1x	16,67	2x	33,33	2x	33,33	1x	16,67	-	2,50	1,05
I have no trouble in using ...	1x	16,67	-	-	4x	66,67	1x	16,67	-	2,83	0,98
The information given in t...	-	-	-	-	6x	100,00	-	-	-	3,00	0,00
As a whole, the PBL-tool is..	1x	16,67	-	-	5x	83,33	-	-	-	2,67	0,82



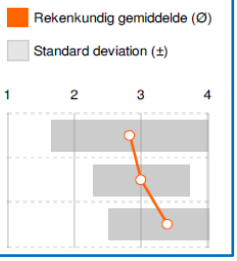
4. Using the web-based PBL-tool would give me..... *

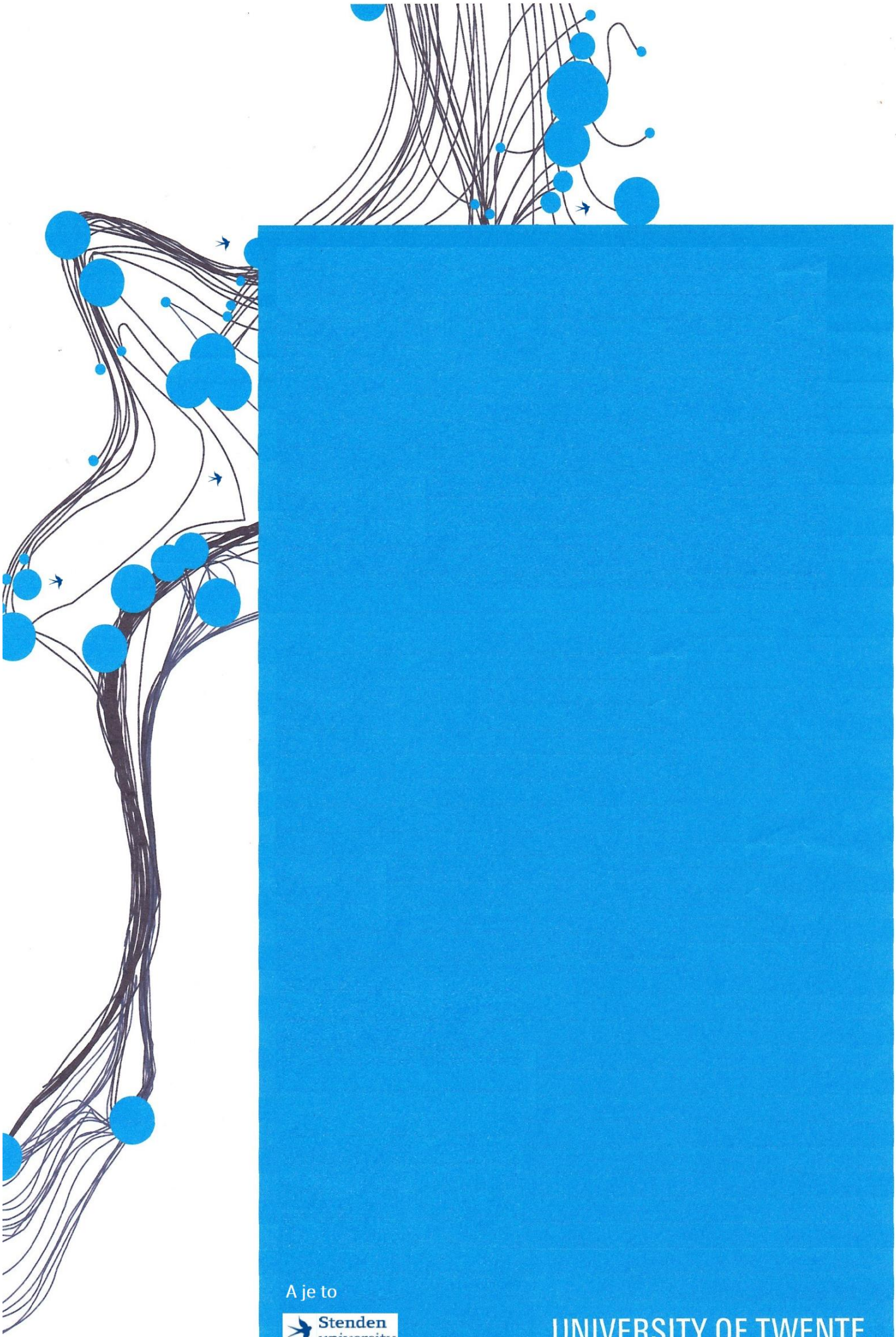
	Not (1)		A little (2)		Quite (3)		Indeed (4)		(no opinion) (0)		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
a better opportunity to exp..	1x	16,67	-	-	2x	33,33	3x	50,00	-	3,17	1,17
a sense of self-control on t..	1x	16,67	-	-	3x	50,00	2x	33,33	-	3,00	1,10



5. When having more PBL-tutorials..... *

	Not (1)		A little (2)		Quite (3)		Indeed (4)		(no opinion) (0)		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	Ø	±
I intend to use the PBL-too...	1x	16,67	1x	16,67	2x	33,33	2x	33,33	-	2,83	1,17
I intend to increase my us...	-	-	1x	16,67	3x	50,00	1x	16,67	1x	3,00	0,71
I would use the web-based...	-	-	1x	16,67	1x	16,67	3x	50,00	1x	3,40	0,89

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