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In search of design principles for developing digital learning & performance support for a student design task

A digital learning and performance support environment for university student design tasks was developed. This paper describes on the design rationale, process, and the usage results to arrive at a core set of design principles for the construction of such an environment. We present a collection of organizational, technical, and course-related requirements that led to the particular choice and setup of the targeted environment. Building upon the established learning management system "Moodle", we designed a backbone structure called Product & Process that fitted onto the ASCE intervention model. Within the four phases of this model, students could find activity checklists, tools, and background information to support their design activities. In addition, the environment was supplemented with tools for group Communication and collaborative Report writing. The environment has been used for 5 weeks by 35 students who worked in small groups on a design task. We analyzed the students' appraisals for usability, and examined usage data from their action logs. The results indicated that the students were positive about the environment, and generally used its facilities fairly frequently. The discussion revolves around the issue of how to achieve a balance between constraints, freedom, and scaffolding. In addition, a set of design principles is proposed for the constructing of a future version of a learning & performance support environment.

Introduction

The University of Twente, founded in 1961, was originally a purely technical university. Students could earn an engineering degree in electrical, mechanical or chemical engineering. The University broadened its educational horizon in the mid-seventies when it opened a faculty for the social sciences. In the year 2002, a psychology department enriched this faculty. Recently, the Board of Directors of the University gave the stimulus for an important renovation of the curriculum for the bachelor programs in all faculties. This led to a uniform roster that better facilitated students to choose from the courses offered throughout the University. A second major change was that the engineering approach should be the pivotal point for the didactic approach in the new curriculum in all faculties. In each semester, a set of modules was offered; each presenting a combination of theory, skills training and design tasks. In a design task, students work in teams to construct a solution for a real or realistic problem. The realization of that solution should be supported by a digital environment. This paper discusses the development of that environment (called TOM: "Twents Onderwijsmodel", English: "Twente Educational Model", an acronym generated from the name of the University's new educational program) for second-year psychology students.

This paper offers an example of the 'design and construction' phase of design research (McKenney & Reeves, 2012). This phase involves rational, purposeful consideration of knowledge and concepts that can be used to address specific problems in practice. As potential solutions are generated and explored, the underlying theoretical and practical rationales are elaborated. This allows the design framework to be evaluated and critiqued. The present paper describes a framework for supporting student learning by design, along with its theoretical and empirical grounding. The leading questions in this paper are: (1) What are the design principles for building a digital learning and performance support environment for a student design task? (2) What do usability findings tell us about the learning environment and its design principles? The approach we took to address these questions is that of developing the environment first, and then to reflect on what we did and why. The approach is also qualified as "reflective practice" (McKenney, 2008). According to Alan Schoenfeld (1999), such an approach lies at the heart of design experiments. That is "Sometimes you have to build something to see if it will work. Without stopping let me add: and then you have to study the hell out of it. We don't do nearly enough of that." (pp. 12).

The set-up of the paper follows the steps in the development process. Thus, it begins with a design rationale, and then progresses into the design requirements, actual design, testing and reflection at the end in which we advance a set of design principles. First, we introduce the three pillars of the learning by designing approach (LBD) that provided the backbone for the design of our learning and performance support environment. Thereafter, we describe the organizational, technical and course requirements for the environment. Next we describe the course module as a whole and the place of the student design task. Thereafter, we describe its actual design, and report on the usability outcomes that were obtained from action logs and student appraisals of the environment. We conclude by advancing a set of design principles, and we discuss the opinion that a learning and performance support environment must find a balance between constraints, freedom and scaffolding.

Educational design research is undertaken to achieve twin goals of yielding both practical and scientific outcomes. In this study, the design principles and examples given constitute a practical contribution for those interested in designing similar modules for use in higher education. The theoretical contribution of the paper is explorative (not confirmatory) and takes the form of new hypotheses based on the design and evaluation experiences described.

Grounding the initial design

The design researchers creating the new course module (also the authors of this paper) have been teaching courses about design to the target group and using an LBD approach for many years. Also, the time available for design work did not allow for a formal needs and context analysis phase. Therefore, the design researchers relied on their existing knowledge about the broader module structure, the target group as well as recent literature to shape initial design. This section describes four key sets of ideas underpinning the initial design: Context, Student needs, LBD and Usability.

Context

The broader context for TOM is the module “Psychology in Learning and Instruction” which is given in the first semester of the second year of the Bachelor course “Psychology”. This module (15 EC, comprising a total of 420 study hours) consisted of three parts:

- Theoretical part about Learning and instruction (“Theory” – 5 EC)
- Methods and techniques part (“Skills lab” – 5 EC)
- Design and evaluation part (“Design task” – 5 EC)

The parts were scheduled in sequential order. In the theory part, students develop an initial understanding of how people learn and how instruction can promote the learning process while taking into account individual differences in age, cognitive development, and motivation as well as prevalent learning deficiencies such as dyslexia and dyscalculia. This theoretical knowledge is ‘brought to life’ in the skills lab where students prepare and deliver mini-lessons to their peers, and investigate the learning activities and learning outcomes in these lessons given by their peers. Armed with their theoretical and practical background and experience, students start their design task in which they design an instructional intervention.

More specifically, the students are asked to construct an interactive learning environment about nutrition (e.g., healthy food, weight problems, a good energy balance). Students could follow their own interests, more or less, with regard to: (a) the specific topic they wanted to aim for, (b) the kind of intervention they planned to design, and (c) the intended audience for the intervention. To complete the design task, students must follow the four steps in the design cycle described by the ASCE model. Especially the design and evaluation phases are considered to stimulate students to apply previously acquired knowledge as they work on this authentic problem.

In the five weeks in which the student design task ran, a project room was reserved each week for two voluntary 2-hour sessions. Groups could meet each other during these sessions and exchange ideas. In addition, the teacher was always present for consultation and advice. In the final, obligatory session, each group had to present its prototype and hand-in the report. The learning goals of the design task were the following:

- Formulate learning goals and to make reasoned choices for instructional design theories to reach these goals.
- Transform goals and theories systematically into a design and prototype of an interactive learning environment.
- Perform and report on a small formative evaluation of the prototype.
- Cope with the difficulties in management of, and communication within a cooperative design task.

Student needs

Students were in the first semester of the second year. In the first year they already had experience with the new curriculum and with design tasks. The tasks in the first year of the psychology curriculum, however, were heavily structured. Students got a lot of support and feedback from their tutor during the design process. In the second year they got more freedom and the tasks were more open. Students appreciated this but they also indicate that they would have liked some guidelines and tools to support their design process.

35 Students participated in the design task (28 females and 7 males). Students worked in self-formed groups. There were six groups of 4 students (A, B, C, G, H, I), and three groups of 3 students (D, E and J). One group consisted of two students (F).

Learning by designing (LBD)

Current approaches to teaching and learning generally tend to be characterized by three aspects: (a) activity, (b) task authenticity, and (c) technology. Students should be actively engaged in problem solving activities, meaning mental engagement with the subject matter, which has since long been considered vital for learning (Wittrock, 1974). Mayer (2008) has elaborated this view by proposing a distinction between three activity types, namely selection, organization and integration. Each activity type refers to a particular phase in information processing. Selection concerns the first phase in which information must be selectively attended to. Organization refers to mentally constructing a coherent structuring of the information. In integration students must connect the new information to the prior knowledge they already have on the topic.

In addition to emphasizing activity, students should also become more engaged in solving real or realistic tasks. The insight that students needed more practice in solving realistic problems emerged as a reaction to the finding that students' knowledge too often remained inert. Students found it hard to apply what they had learned in school in their jobs. This finding provided an important stimulus for the rise of the constructivist approach in education (Bransford, Brown, & Cocking, 2000; Resnick, 1987).

The third aspect in current educational approaches is the functional integration of technology (Spector, Merrill, van Merrienboer, & Driscoll, 2008; van der Meij, 2012). Technology use in education has always been a heavily debated issue. Each time a new tool (e.g., radio, television, computer) became available, expectations rose that it would revolutionize education. It never did. An important reason is that technology is a means rather than a goal. Technology should be employed because it can serve an important role in achieving the objective(s) of a lesson or series of lessons.

An approach in which these three aspects have emerged is Learning by Designing (LBD). LBD is an activity-centered approach. Student activities should be geared towards the goal of creating a design solution. The type of scientific processes that LBD emulates is that of an engineering approach. Students must engage in a systematic and scientific process of problem-solving that (repeatedly) involves engagement in the processes of selection, organization and integration. In addition, LBD requires students to apply fundamental or theoretical knowledge. In constructing a solution, students must find and use theory to ground their designs. The design tasks in LBD are often real or realistic. The relevance of the design tasks should have immediate intuitive appeal. Carroll's approach to teaching Smalltalk programming can serve to illustrate what this requires of the designer of LBD. Instead of asking informatics students to learn lots of basic programming codes, Carroll presented his students with the design problem to fix a rigged blackjack game. In addition, to being a highly motivating task, the design problem also confronted students with key issues of programming in Smalltalk (see van der Meij, & Carroll, 1998). Technology often serves a supportive role in LBD. For instance, students may be offered a repository of articles and books to speed up their search for pertinent literature. Also, tools are sometimes made available for students to test design solutions.

The presumed benefits of LBD are threefold (compare Du Plessis & Webb, 2011; Janssen & Waarlo, 2010; Vreeman-de Olde, de Jong, & Gijlers, 2013):

- Students develop core competencies of designers. A systematic, iterative approach plays a prominent role as methodological component in this development.
- Students are motivated for what they need to achieve. Their motivation is spiked by the fact that the design task they must tackle is tangible and relevant.
- Students learn to apply knowledge from basic theories. They must translate theoretical knowledge into principles for design that, in turn, must yield design solutions.

Usability

No matter how well-considered the construction of a module, there can be no substitute for measuring what users actually do, think or feel as they interact with it (see Schriver, 1997). In other words, the user should be considered a major stakeholder in design and evaluation. As described above, the (presumed) needs of the students of the module provided input for its construction. For the evaluation of the module, usability testing was applied, where the leading question is how well a design actually works, and can be done concurrently and/or retrospectively.

In concurrent testing, information is gathered real-time. A typical example is the think-aloud method in which users are asked to verbalize what they are thinking while doing. The method that we chose to gather real-time information was user logs. Compared to think-aloud protocols, user logs have the important advantage that they are unobtrusive, and that they can quickly and easily provide accurate information on what students do. User logs can be explored to discover new or unforeseen usage, or they can be searched for data that can address a specific research question. In this study, befitting the focus on supporting learning by doing, user logs were searched for information about the frequency of tool usage.

In retrospective testing, the user is asked to look back and reflect on what has occurred. Such reflections are typically measured with a questionnaire, interview, critical incident approach or comprehension test. In view of the limited time for testing (both from the designers and students), a questionnaire approach was selected to gather information about how the students think or feel about TOM. The questionnaire focused on the three critical aspects of usability distinguished in a famous publication by Bethke and her colleagues at IBM (Bethke, Dean, Kaiser, Ort, & Pessin, 1981). According to this study, people find information easy to use when it is: (a) easy to find , (b) easy to understand, and (c) task-sufficient. The first aspect refers to accessibility. TOM-students should have little trouble locating the information they are looking for. The second aspect addresses the issue of comprehensibility. Usability is at risk when students cannot quickly grasp the meaning of an article, book or tool. Finally, task-sufficiency refers to presenting information and tools that are relevant and sufficient for the task at hand. All essential information needed to do the task should be included.

Design requirements

The design of a digital environment for the student design task should fit the LBD approach that we adopted. Our foremost design consideration for this construction concerned the choice for a methodology that could scaffold the students' systematic and scientific process of designing. The obvious candidate for this selection was the Analysis, Synthesis, Construction, and Evaluation model (ASCE-model). The ASCE-model concentrates on psychological interventions (Wiering, Pieters, & Boer, 2011). It has been introduced to the psychology students in their first year. Now being in their second year, students are still regularly reminded of that model in classes.

The ASCE-model distinguishes four core design phases or steps: Analysis, Synthesis, Construction, and Evaluation. It resembles the method for problem solving described by Polya (1945) who discerned four phases: ‘understanding the problem’, ‘devise a plan’, ‘carry out the plan’, and ‘looking back’. Analysis comprises the analysis and definition of the problem. Synthesis refers to deciding on the behavioral determinants and to selecting matching methods and strategies for behavior change (the intervention). Construction refers to the concrete program or product, and how that product is used in actual practice. Evaluation focuses on the assessment of the impact of the intervention. The main question in evaluation is whether the desired behavior occurs and learning has taken place. This phase also comprises a process evaluation. For other, non-psychological intervention tasks, similar phases have been described more recently by Jonassen (1997) or Carlson and Bloom (2005).

Each phase consist of several activities that should be performed in sequence (and possibly iteratively). For instance, during Analysis students should first engage in an exploration of the design task and the conditions in which it occurs. Generally, students should therefore ask questions such as “What is the problem?”, “When does the problem occur?”, “How prevalent is the problem?”, and “How serious is the problem?” This should then be followed by a deliberation (e.g. brainstorming, drawing a concept map) on the intervention objective and a means of measuring its accomplishment.

Course requirements. The presentation of the ASCE-model in TOM should serve several functions, all of which concern the course itself. First, it should remind students of the ASCE-Model as the leading framework, and should give a succinct description of the main input and output expected from each phase. It should enable students to easily perform checks on the execution of their actions in each phase, and include tools to facilitate certain activities. These considerations led to the following set of Course Requirements (CR):
CR1. The system should present the ASCE-model and make a distinction between its four phases.
CR2. The system should contain a checklist with the activities for each phase.
CR3. The system should contain tools that support the different activities in each phase.
CR4. The system should contain relevant background information related to the phases/activities.

Organizational requirements. The organization of the design task led to another set of considerations. One factor concerned teamwork. Real design projects are often conducted in multi-disciplinary teams, where the collaboration not only brings different kinds of expertise into the design, but also the conversations among the team members stimulate the articulation and discussion of design options (see Jonassen & Rohrer-Murphy, 1999). In TOM students had to work in teams of 2 to 6 persons. In addition, the design activities of individual members should be coordinated and should result in a single design solution for the group. For this reason, TOM should offer communication support.

Students nowadays have lots of different ways of communicating with each other, so why integrate communication in TOM? One reason is to offer students a single environment in which they could do all they needed to do for their design task. We considered that constructing an all-inclusive environment would facilitate communications across groups. For instance, it was deemed to come in handy for sharing when a group has found an interesting new application or pertinent information that is relevant for all groups.

Another factor was the consideration that a communication section should also serve the teacher in the course. In his/her role as counsellor (to give specific advice on a group’s current design approach) or as a supervisor (to intervene in a group’s collaboration or planning if necessary), it was considered desirable that the teacher could (re)view the existing group communication and could self-initiate an interaction with a group or a member of a group.

Finally, an important organizational requirement was for all groups to hand in a single report describing their design process and illustrating their product. For reporting the same consideration of all-inclusiveness was followed. That is, the students should easily be able to copy - paste sections of what they had communicated or built in TOM into their report. In addition, it should be easy for them to merge contributions of individual team members into a group report. Thus, the following set of Organizational Requirements (OR) was drafted:

OR1. The system should facilitate communication between all course members.
OR2. The system should facilitate information, file and link sharing between all course members.
OR3. Each group should have a specific group space that is only accessible to the group members and their tutor.
OR4. The system should facilitate communication between subgroup members.
OR5. The system should facilitate file (and link) sharing between subgroup members.
OR6. The system should facilitate collaborative report writing between subgroup members.

Technical requirements. The technical requirements identify and describe a set of features and characteristics that the learning and performance support system needs to fulfil from a technical perspective to create a maintainable, flexible and usable system.

For reasons of grading and the assignment of credit points, the system needs to be able to authenticate against the university's student account system. The identity of the user needs to be clear and unambiguous. Ideally, existing authentication mechanisms can be used for this purpose. Also, with the increasing availability and usage of mobile devices such as smartphones, iPads and tablets in everyday life, the system need to support these devices with respect to varying screen sizes and alternative input modalities. Because students are expected to carry out a considerable part of their work in various places outside the classroom (e.g., at home, in the library, while commuting), it was considered important to address these by applying responsive design principles (Gardner, 2011). That is, the visual layout, available features, and input methods had to adapt to the used device.

In addition to the distribution of learning resources and information, the system also had to support the integration of interactive applications as "activities" in the various phases. This integration needs to be as seamless as possible to improve the user experience and to reduce media breaks. Examples for interactive applications are concept mapping tools, collaborative writing tools (incl. wikis), design prototype building tools etc. The use of web-based technologies (e.g. browser-based applications using JavaScript, HTML5 etc.) allows an easy integration of various applications in one common environment. As a consequence of the requirements concerning group work and communication, the envisaged environment needed to support the creation and administration of student groups. This led to the following set of Technical Requirements (TR):
TR1. The system needs to authenticate users against the university's student register.
TR2. The system needs to support mobile devices and needs to follow responsive web design principles.
TR3. The system needs to allow the integration of interactive applications.
TR4. The system needs to support the creation and administration of student groups.

TOM structure

Following the Course and Organizational Requirements, TOM has been structured into a common introductory part for general course information, and a core part with the sections "Communication", "Product and Process", and "Report" in which the major information and tools for achieving the design task were given (see Figure 1). This structure is visualized in Table 1. Because the introductory part is common in many Learning Management Systems, we will not elaborate its design and usage.

Table 1
Structure for TOM.

common for all students and teachers	Introduction, Information and General Topics					
one instance (copy) per student group	Communication	Product and Process				Report
		Analysis	Synthesis	Construction	Evaluation	

The three sections "Communication", "Product and Process", and "Report" each receive their own place and visual presentation in TOM. Also, a brief, one or two sentence description explains the content covered by each section.

The section “Product and Process”, which stands at the center of the structure, was further subdivided into the four steps of the ASCE-model. (CR1). Furthermore, within each step information was presented about (a) Goals and Activities, (b) Tools and (c) Background Information (CR2, CR3, CR4, see Figure 2). These components have been formatted following an Information Mapping approach (Horn, 1993), i.e. each component had the same visual design and fixed position throughout TOM to facilitate navigation and access. This section was designed to support the students’ core task – to design a psychological intervention in the area of health education.

The “Communication” section presents four different, technical means for communication - to discuss, to exchange ideas, comments, to share files or to create link collections (see Figure 1). Although communication between project group members is expected and important throughout all activities in TOM, it has been decided to make this a distinct section to prevent fragmentation of communication activities and to ease transfer and integration of communication results. As a side effect, the use of communication tools in (online) group activities can foster collaborative learning skills (Khalil & Ebner, 2013). The use of this section was not obligatory, but it served as an overall support to enhance the group collaboration. Students did not receive instructions on how they are expected to use this section; the use of the “Communication” section was completely free and optional.

Similar arguments hold for the section “Report” (see Figure 1). Here, two different collaborative writing tools were provided and a plain “upload report” option. Writing the design task report relates to all sub-activities; particularly it collects results from the Analysis, Synthesis, Construction and Evaluation sub-sections, and to this end an overarching, separate “Report” section has been added. This section reflects the students’ final task – to write and hand in a report on their process and results from their core task. Similar to the “Communication” section, the use of this section was non-obligatory; students were allowed to use any word processor and could hand in their report via e-mail.

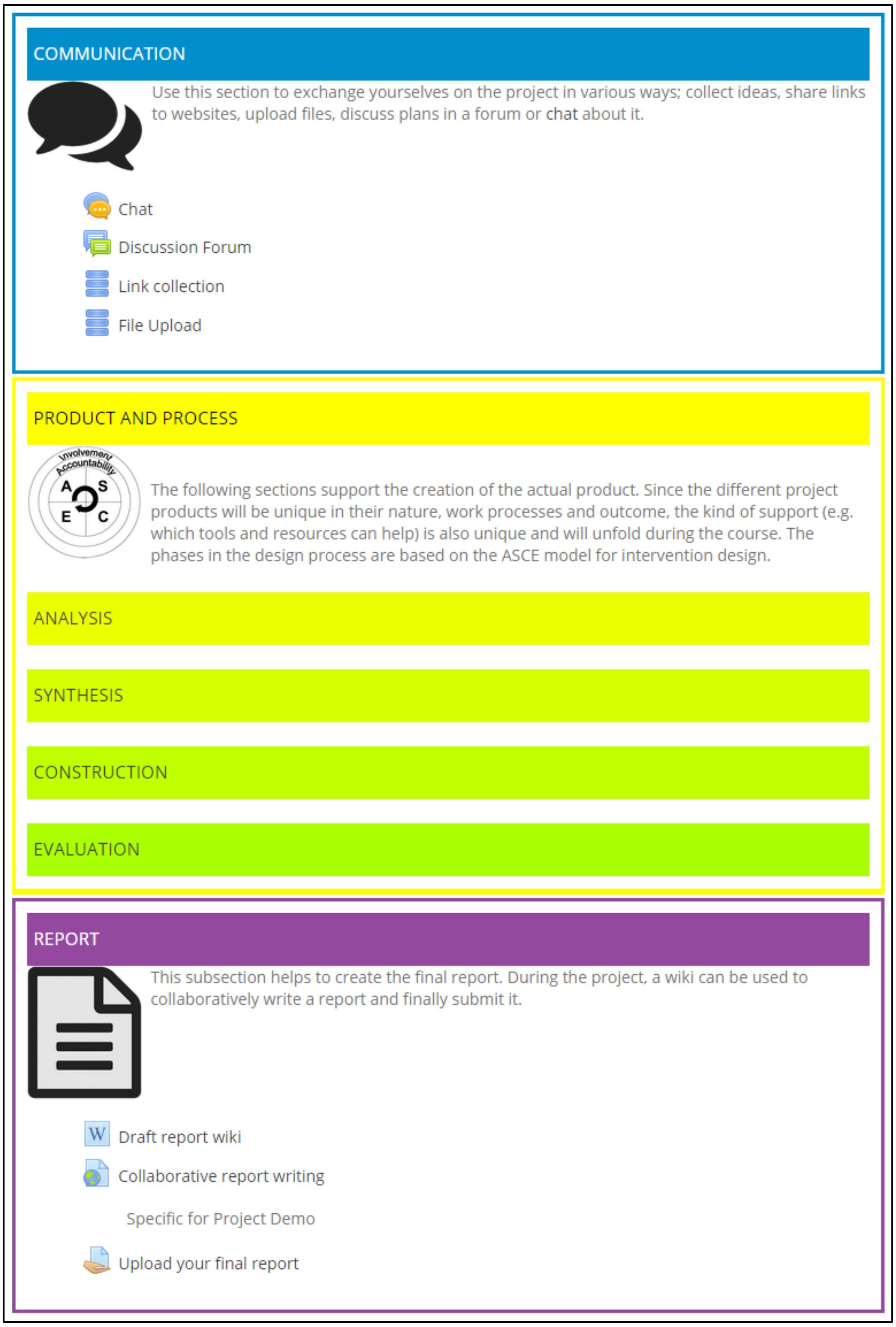
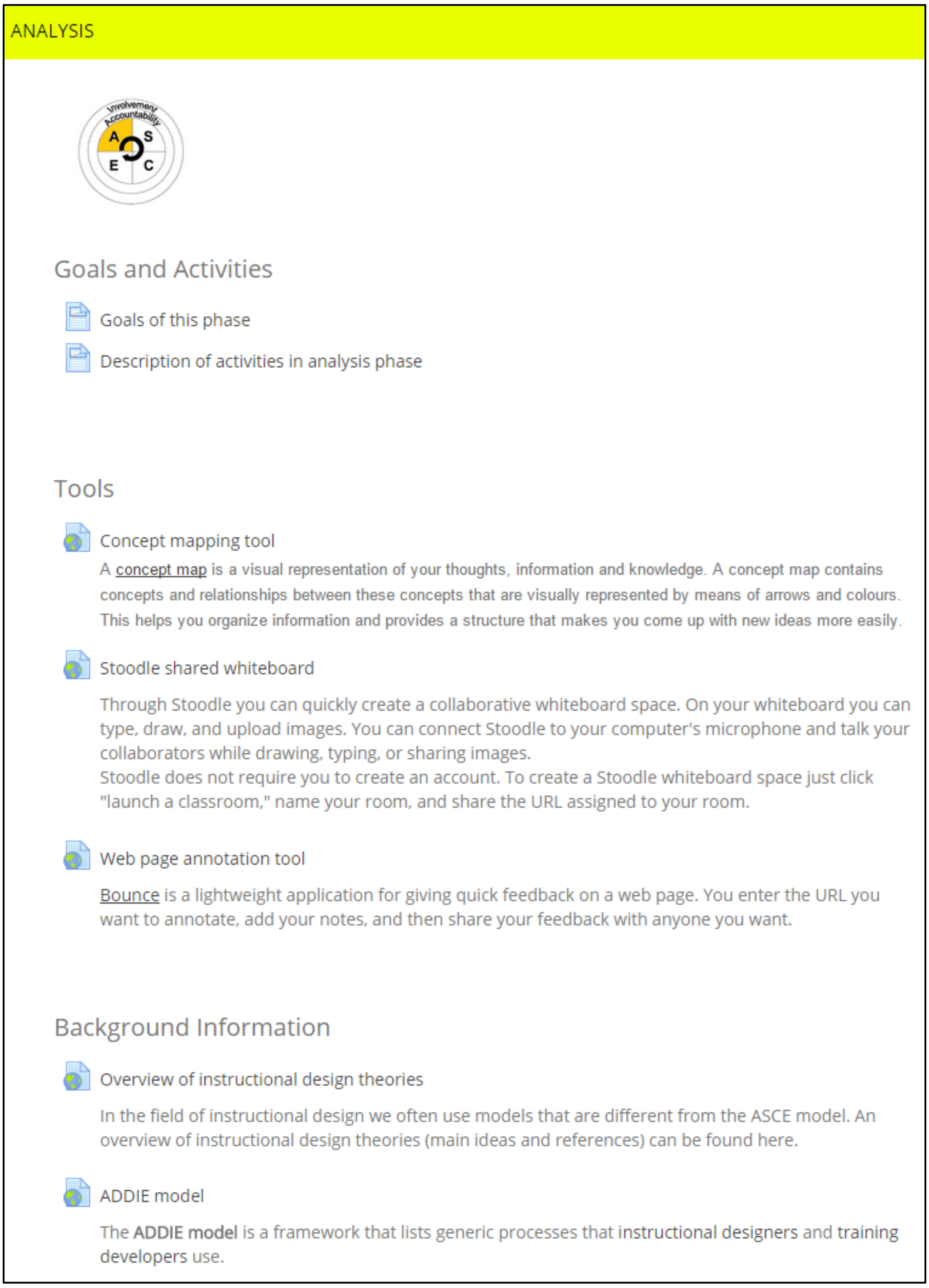


Figure 1. The overall TOM-structure with the sections “Communication”, “Product and Process”, and “Report”.



ANALYSIS

Goals and Activities

Goals of this phase

Description of activities in analysis phase

Tools

Concept mapping tool

A concept map is a visual representation of your thoughts, information and knowledge. A concept map contains concepts and relationships between these concepts that are visually represented by means of arrows and colours. This helps you organize information and provides a structure that makes you come up with new ideas more easily.

Stoodle shared whiteboard

Through Stoodle you can quickly create a collaborative whiteboard space. On your whiteboard you can type, draw, and upload images. You can connect Stoodle to your computer's microphone and talk your collaborators while drawing, typing, or sharing images.
Stoodle does not require you to create an account. To create a Stoodle whiteboard space just click "launch a classroom," name your room, and share the URL assigned to your room.

Web page annotation tool

Bounce is a lightweight application for giving quick feedback on a web page. You enter the URL you want to annotate, add your notes, and then share your feedback with anyone you want.

Background Information

Overview of instructional design theories

In the field of instructional design we often use models that are different from the ASCE model. An overview of instructional design theories (main ideas and references) can be found here.

ADDIE model

The **ADDIE model** is a framework that lists generic processes that instructional designers and training developers use.

Figure 2. The "Analysis" activity sub-section with an overview of the main components “Goals and Activities”, “Tools”, and “Background Information”.

Learning Management System (LMS)

Following the Technical requirements, a Moodle (version 2.7, see https://moodle.org) environment was chosen as the target environment for TOM. Among the many available Learning Management Systems ("LMS", e.g. ILIAS, see http://www.ilias.de; Sakai, see https://www.sakaiproject.org; or Blackboard, see http://www.blackboard.com), Moodle has the advantage that it is free, open source, and can draw on a large community of developers, teachers and students. Moodle can also be easily installed in the local organization's infrastructure, as it runs on standard server configurations. It addition, its plug-in based architecture facilitates the usage of existing components along with the instalment of new, self-developed features. Another advantage is that the design and layout of the environment can be easily adapted and modified.

Moodle can authenticate users against an external LDAP server ("Lightweight Directory Access Protocol"), which was supported by the university's infrastructure. This feature realized requirement TR1. Moodle developers have also recently increased the support for mobile devices. They have introduced responsive web design, making it usable on devices like smartphones or tablets as well. Furthermore, native Android and iOS apps are available, for an even more tailored access to the environment. This feature realized requirement TR2.

With a default installation of Moodle, many interactive applications (so-called "activities") are already available (e.g., a forum, file sharing, chat, quizzes, surveys, or a wiki). Plug-ins created by third-party developers are available as well, which increases the number of potential applications. In addition, it is possible to seamlessly integrate external (interactive) web-pages and web-applications, like an external concept mapping tool or Google Docs for synchronous editing of text documents. These features realized the requirements OR1, OR2, OR6, and TR3.

As a standard feature of many LMSs, Moodle supports the flexible creation and organization of groups. Students can be assigned to courses, and student groups can be created flexibly to work on group assignments. These features, together with the course structure described above, allows to establish communication with the whole group of students, with a sub-group of students or with individual persons, thus realizing requirements OR3, OR4, OR5, and TR4.

Summarizing, Moodle already provides many features that are needed for the realization of the given requirements, and its Open Source characteristic makes it an ideal candidate for necessary adaptations and extensions.

Method for student evaluation of TOM

To gather information about the students' actions in TOM, all user actions were recorded with an extensive logging system. The action logs contain information about who performed which action, at what time, from which IP address etc. Actions typically have the granularity of meaningful usage of TOM, such as logging into the system, sending a chat message, uploading a file, or clicking a link to an external resource. Table 2 presents two examples of the granularity and content of the action log information. The first row denotes a student action of creating a new forum discussion thread. The second row describes the action of opening an external resource. The actual action logs contain more information like course id, access through browser or app, object identifiers, etc. All in all, the data logs that were recorded in TOM consisted of 6896 student actions.

Table 2
Example of an action log excerpt.

id	Event name	action	target	user id	time	…
11	\mod_forum\discussion_created	created	discussion	40	1414665404	…
13	\mod_url\course_module_viewed	viewed	url	23	1414054234	…

Making use of the (technical) availability of tracking student activities provides opportunities for gaining insights into the actual usage of a (digital) learning platform, in contrast to e.g. knowledge gain test designs or students' self-reported usage of a system. These techniques are not innovative by itself, and have been widely used in various approaches for many years, e.g. for gaining information on the usability of systems (Hilbert & Redmiles, 2000), or to realize Intelligent Tutoring Systems (ITS) with the help of educational data mining techniques (Romero & Ventura, 2007). Consistencies and/or mismatches between action log information and other observed information can help to better understand student activities and can lead to the re-design of aspects of the learning platform, as described in more details in later sections.

Granularity. During the five week period that the design task ran we regularly saw groups of students spread across the building to work on their assignment. In doing so, students frequently flocked around a single computer that was connected to TOM. This observation meant that an analysis of the action logs of individual students would give a very inaccurate picture. Therefore, all further action log analyses concentrated on the merged findings of all group members, i.e., the action logs of the single group members have been plainly concatenated for further analyses. Figure 3 gives an overview of the overall number of actions per group in TOM. The data show considerable variation. The numbers of actions range from a minimum of 2 (group J) to a maximum of 696 (group E), with an average value of M = 329.3 (SD = 202.5).

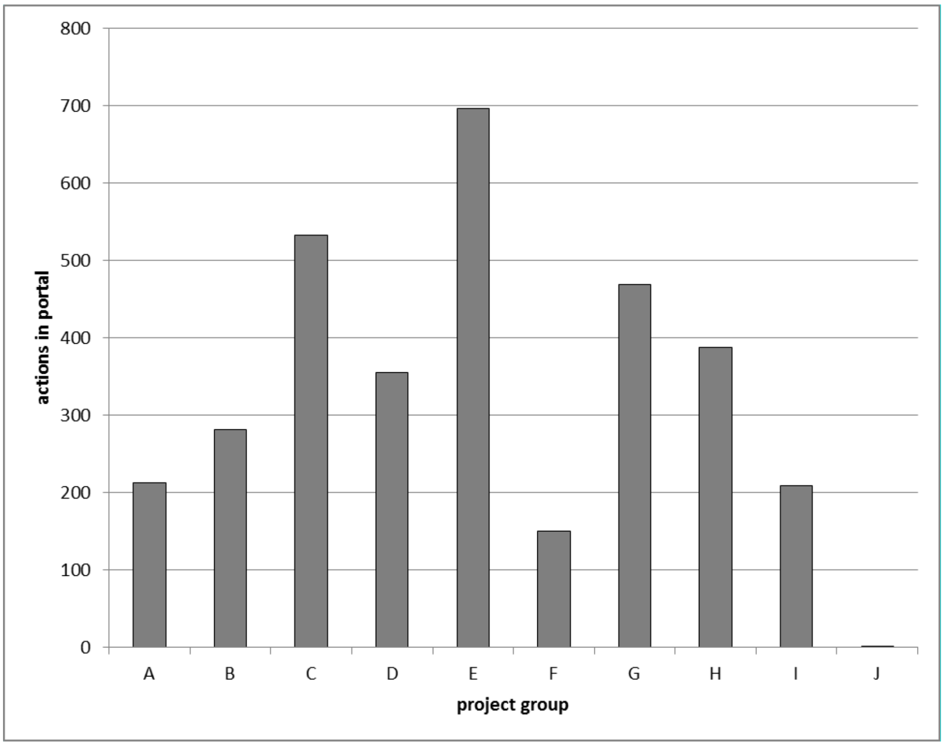


Figure 3. Number of actions of each group (A through J).

Location and active hours of TOM-usage. The recorded IP address of the device used to access TOM, gives some insights into the location from which the student gained access. Out of a total of 4201 actions, about 61% have been performed from within the campus network, whereas 2695 actions (about 39%) originated outside the campus. These numbers have to be read with some caution, however, because students living on campus, and students accessing TOM through a VPN connection were both counted as access from within the campus network.

Another impression of the students' work context, i.e. their most active hours, can be won from the distribution of actions over daytimes, as presented in Figure 4. It shows that most actions, about 89%, have been conducted between 8 a.m. and 8 p.m., with a peak of 1149 actions between 9 and 10 a.m. The lowest value with 9 actions lies between 5 a.m. and 6 a.m. The peaks between 9 and 11 a.m. fit with the classroom sessions in the course.

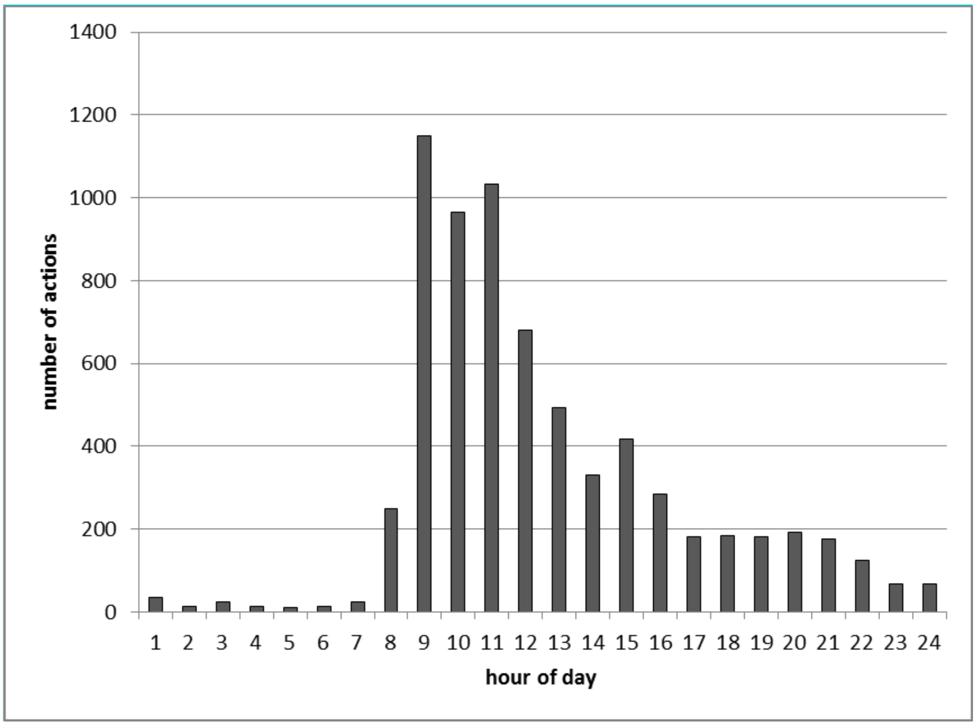


Figure 4. Distributions of actions over the day

To assess the students' opinion about TOM a short one page paper usability questionnaire was designed. For TOM as a whole, as well as for each of the three sections (i.e., Communication, Product & Process and Report), the questionnaire consistently asked the three core questions posed by Bethke et al. (1981), namely whether:
(1) Information was easy to find,
(2) Tools were easy to use, and
(3) Tools were useful
Students could indicate their level of agreement with each question on a 7-point Likert scale with the number 1 representing total disagreement, and the number 7 representing total agreement. After the twelve closed questions, an open question was posed whether students had any special likes or dislikes that they wanted to tell us about. The answers to these open questions were grouped into categories and tallied for frequency. The questionnaire was administered at the close of the last session, after the students had presented their prototype and handed-in their report. 31 students filled in the questionnaire.

Results

Actions and Opinions for TOM as a whole

Figure 5 shows the distribution of actions per group in the three sections "Communication", "Product and Process", and "Report". For many groups (A, C, E, G, H, and I), usage of the communication tools produced most of the actions in TOM. Some groups (B, D, and F) used these tools less frequent. The predominant usage data in these groups came from the "Product and Process" section. In line with the data presented earlier in Figure 3, group J did not use TOM at all. (The two actions from group J as reported in Figure 3 originate from accessing the platform, but no material or tool has been used.)

Table 3 shows the outcomes of the student's overall appraisal of TOM as a learning environment. The average scores for the environment were just above the median of the scale. The high value of the standard deviation indicates that there is a large variety in students' opinions, especially about the usefulness.

Table 3

Students opinion about TOM as a whole.*

Statement	*Mean (standard deviation)*
Information was **easy to find** (N = 31)	4.45 (1.59)
The environment was **easy to use** (N = 31)	4.61 (1.17)
The environment was **useful** (N = 31)	4.52 (1.88)

**The scale values range from 1-7 (more meaning, more positive); 4 = median value*

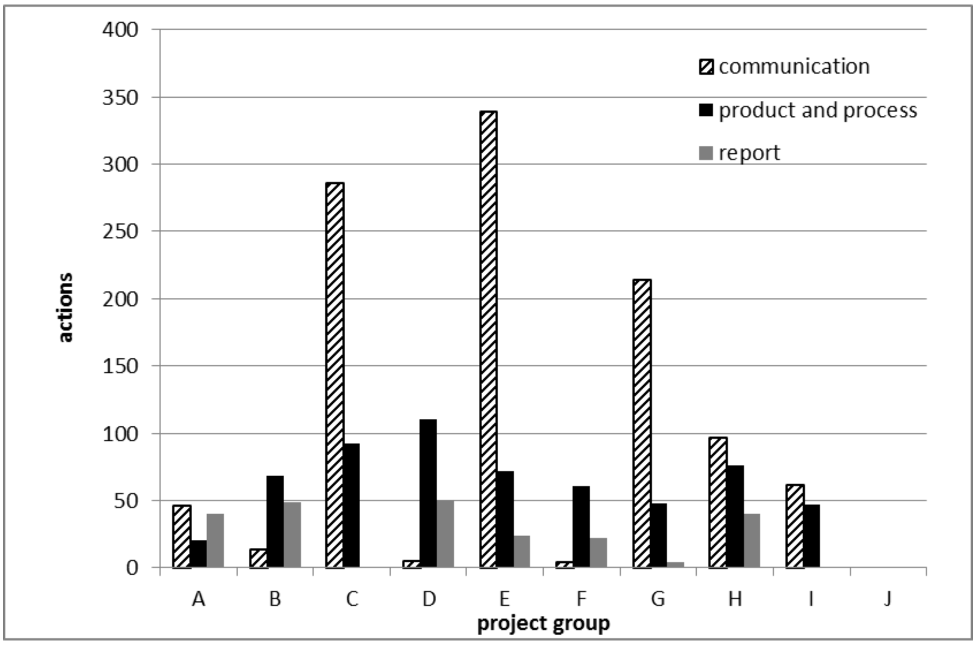


Figure 5. Actions in TOM sections "Communication", "Product and Process", and "Report" per group.

The answers to the open question in the questionnaire revealed that students were positive about the all-inclusive nature of TOM. They liked that everything they needed for their design task was available in one place. In addition, they mentioned that TOM provided them with useful references. Some students stated that they had not used the communication and reporting tools in TOM a lot because of other alternatives, preferring instead tools like “WhatsApp” and “Facebook” for communication and “Google Drive” for reporting. Another argument for low usage of these tools was that communication and reporting were already reasonably well supported by the voluntary sessions in which they met face-to-face with their team members. Some students expressed technical objections, stating that they didn’t like the tools to open in a window inside the environment because they couldn’t resize the window.

While likes were also frequently expressed for the sub-section “Description of activities in a phase” (see Figure 2), this section was not considered ideal. The activities description constituted a checklist. The checklist was designed as an authentic job aid by offering a comprehensive list of potential issues that could be of relevance to most design tasks.

A prioritization of tasks was not included in the description, as this was expected to be discussed and decided by the students themselves. However, instead, this lead to a slight disarray and little usage of the proposed tools. Further, some students indicated that they would have appreciated a demonstration of the tools in earlier design task meetings, as well as a better linkage to the activities (rather than the just the phase) they supported. Had we done so perhaps it would have raised usefulness and ease-of-use, while also affording the opportunity to explain to students the importance of developing and exercising their own judgment (regarding which tasks are essential or not) to serve specific design challenges.

Actions and Opinions for Communications in TOM

The actions of each group in "Communication" are shown in Figure 6. The figure also shows the usage of the various tools that available in this section of TOM (i.e., chat, forum, link collection, and file upload). The values range from 0 actions (e.g., chat actions in group A) to 308 actions for file upload in group E. It can further be seen that each communication tool has been used extensively by at least one group, and that not all groups used all tools. Groups E and G strongly favored the use of the file upload tool, while group J did not use any communication tools at all. Group C used mainly the forum, while group A about equally used the file upload and link collection tools. Group F is special in that it merely and incidentally used the link collection tool.

Exemplarily, we compare the actions for the two groups with the highest usage count in this category in detail: Group E, altogether 339 communication tools-related actions, 3 chat-related actions, 3 forum-related actions, 26 link collection-related actions, 307 file upload-related actions versus group C, altogether 286 communication tools-related actions, 5 chat-related actions, 270 forum-related actions, 4 link collection-related actions, 7 file upload-related actions. Although both groups have a comparable overall action count, the distribution of actions over the various communication tools differs considerably. While group E barely used the forum and made some use of the link collection and extensive use of the file upload tool, group C extensively used the forum above all other tools.

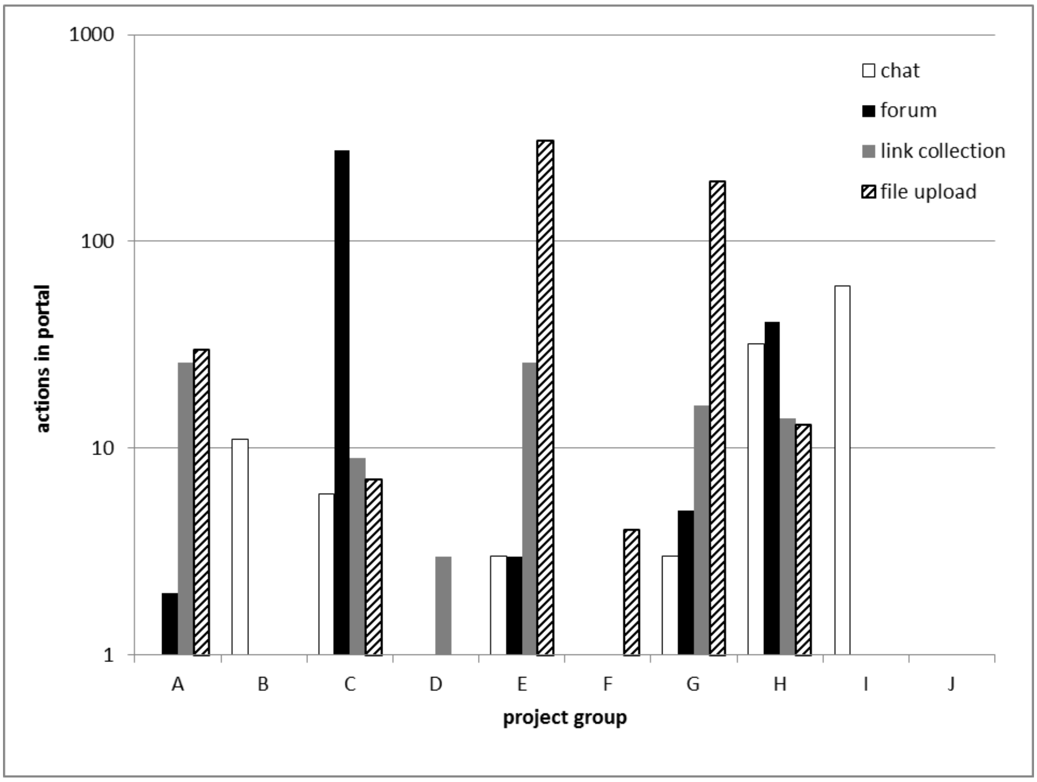


Figure 6. Actions per group for tools in the section "Communication" (Please note: The Y-axis is a logarithmic scale for better graph visualization).

Table 4 shows the outcomes of the questionnaire for Communication. The ratings of the students were all slightly above median value. In other words, they were neither very negative, nor very positive about what Communication had to offer.

Table 4
Students' opinion about Communication.

Statement	*Mean (standard deviation)*
Information was **easy to find** (N = 28)	4.54 (1.14)
The tools were **easy to use** (N = 28)	4.89 (1.20)
The tools were **useful** (N = 28)	4.21 (1.69)

**The scale values range from 1-7 (more meaning, more positive); 4 = median value*

Actions and Opinions for Product and Process in TOM

The "Product and Process" section supports students in their core activities for the design task. The information on Goals & Activities has been accessed most with a frequency of about 8 times on average per group (M = 7.6, SD = 7.9). Beyond that, the usage data give a highly diverse picture. The average tool in the ASCE sections has barely been used (M = 1.3, SD = 2.5). There are several probable causes for the under-usage. One is that a high number of tools was made available, some of which serving the same goal in a slightly different way. Another reason is that some tools were simply not relevant for the kind of intervention that a group had decided to develop. We nevertheless kept these tools in the TOM environment to maintain consistency across groups. All in all, the usage data for this section suggest that there is a need for more guidance and scaffolding.

A repeated measures analysis comparing the three TOM-sections showed a significant effect, $F(2, 50) = 3.45$, $p = 0.040$. The mean scores for Communication, Product & Process and Report were, respectively 4.56, 4.95 and 4.21. Post hoc analyses (LSD-statistic) revealed that the only significant difference was that between Product & Process and Report ($p = 0.049$). Table 5 shows the detailed outcomes of the student questionnaire. For all three usability questions the ratings for this TOM-section were higher than for the two other sections. A repeated measures analysis showed that there was a significant difference only for the factor "easy to use", $F(2, 50) = 4.72$, $p = 0.013$. Post hoc analyses again revealed that the appraisal for Product & Process differed from that of Report ($p = 0.024$).

Table 5
Students' Opinion about Product & Process.

Statement	*Mean (standard deviation)*
Information was **easy to find** (N = 31)	4.90 (1.25)
The tools were **easy to use** (N = 31)	5.10 (1.19)
The tools were **useful** (N = 31)	4.48 (1.95)

**The scale values range from 1-7 (more meaning more positive); 4 = median value*

Actions and Opinions for Reports in TOM

The "Report" section supports students in writing their final report. It included three tools: (a) a wiki that afforded simultaneous editing by one person only, (b) a collaborative writing tool that was realized by embedding Google Docs, and (c) a simple file upload tool. The actions performed in "Report" are shown in Figure 7. This figure clearly reveals that usage of Google Docs (M = 21.1, SD = 19.3) was a highly preferred over usage of the wiki (M = 1.6, SD = 4.1). The file upload tools have not been used at all. Three groups had a look at the upload tool, but finally decided to send their report by mail, which is a regularly used option in various courses.

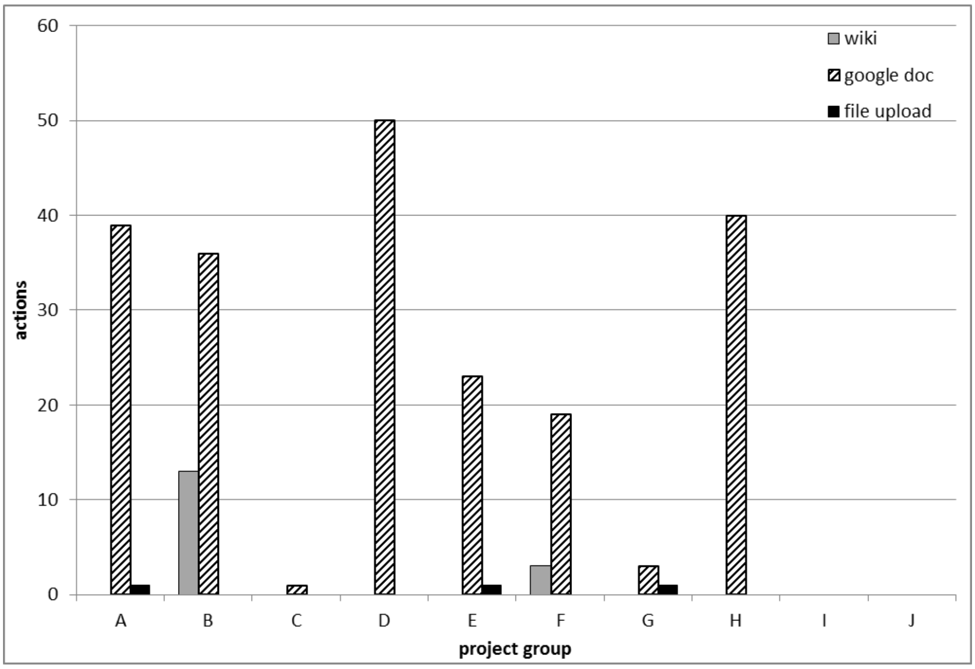


Figure 7. Actions per group for tools in the section "Report"

Table 6 shows the outcomes of the student questionnaire for Report. The ratings for Report were slightly above median value, but even less so than for Communication.

Table 6
Students' opinion about Report.

Statement	*Mean (standard deviation)*
Information was **easy to find** (N = 27)	4.37 (1.24)
The tools were **easy to use** (N = 27)	4.22 (1.34)
The tools were **useful** (N = 27)	4.00 (1.78)

**The scale values range from 1-7 (more meaning more positive); 4 = median value*

Discussion & Conclusion

This project was undertaken as design research, and not simply course development, to reach the twin goals of developing a theoretically and empirically robust TOM module while also producing outcomes that could serve the work of others engaged in similar activities. The TOM module was designed around understanding of the broader educational context, user needs, learning by design guidelines, and usability principles. The first round of testing focused on usability. This section summarizes key findings, discusses their implications and provides recommendations for future research.

The goal of the TOM module was to support groups working on a (psychological) design task. The overall usage of TOM, although not being compulsory, indicates that students showed a basic acceptance and motivation to use the system. Group J, who showed the least active participation in TOM demonstrated an overall lack of motivation in the course and finished with a low grade. Group F also had a low activity score, but this group consisted of only two persons.

In the requirements and actual system design, we aimed at supporting mobile devices and responsive web design as well (TR2). However, in the usage statistics and final investigations we did not focus on this aspect. How mobile devices and mobile learning scenarios can be meaningfully integrated in this approach by, say, making use of student response systems remains to be investigated in future studies (compare Bollen, Eimler, Jansen, & Engler, 2012). The usage statistics of the tools in the category "Communication" (Figure 6) indicate that the different design groups and students follow different collaboration and communication preferences. Although students indicated that they used tools like

“WhatsApp” and “Facebook” to communicate, the various tools in TOM (i.e., chat, forum, link collection, file upload) have been used in different frequencies, and each tool seems to bring an added value to some students. Initially, we had reservations as to whether we should include the section communication at all with so many other affordances for social and other exchanges. Looking back it seems we made the right choice here - the section Communication did serve the students as they were working on their design task.

In the “Product & Process” section, the overview of activities was appreciated and consulted frequently. By and large it served well the purpose for why it was included: as a job-performance aid affording an overview of activities and a check on their (possible) completion. The tools that were offered here were less frequently used. An important reason for this was that students were not acquainted with the tools. They had to find out how they worked and for which tasks and activities they might be useful. Students also let us know that they found this took them too much time. This is in line with the findings of Edmunds, Thorpe and Conole (2012). They concluded “Students also have clear requirements in terms of technology enabling them to produce more in the time that they have, and enabling them to be more effective. Technologies which do not meet these requirements may prove counterproductive or simply be ignored” (p. 83). Striking is that the tool that is the most intuitive (The Padlet wall used for brainstorming) is used most often. Therefore, we recommend to showcase the tools in the first design task meetings and to make a connection between the activity overview and the tools.

Our experiences and results from the Report section suggest that an easy- and intuitive-to-use collaborative writing tool is appreciated and used by students, while a more complex and not fully synchronized tool like Moodle’s wiki tool (only one student was able to edit one page at a time) was barely used. This suggests including other collaborative, web-based production tools in future. Candidates are other Google web-based applications, e.g. Google Sheets (a spreadsheet application), Google Slides (a presentation builder), or the Zoho Office Suite.

Looking back on the development of TOM, three main design principles emerged:

 # 1. Structure the digital environment around the students’ core task.

A learning and performance support system should be organized around the main task or activity of the students. The core component in a digital environment should never snow under. One of the risks is that embellishments or scaffolds obscure the students’ view (or usage) of the component. In inquiry learning students must get to know a mathematical or physical model that can be represented well with a simulation. Therefore, a simulation that affords systematic inquiry should be the center piece.

In learning-by-designing students must put to practice the knowledge and skills they have learned in class. Therefore, the design process should constitute the core component of the digital environment. Design involves a systematic (stepwise and iterative) process in which understanding the construction problem is followed by prototyping, testing a revision. The design process (and the individual stages therein) should be easily accessible in the digital environment. In addition, as instructions about the design process had already been given earlier, the emphasis in TOM became that of giving performance support.

In TOM, the usability data provided some evidence in favor of this principle as the Product & Process section received the highest mean overall appraisal compared to the two other sections. Post hoc analyses further revealed a significant difference with the Report section. In addition, the student appraisals for the three usability questions were consistently highest for this design component in TOM (i.e., the ASCE-Model). In addition, the tools in the Product & Process section received a higher rating as “easy to use” than the tools in the Report section. The usage data further illustrated that TOM satisfactorily functioned as a performance aid. That is, students used TOM to refresh their memory about what each phase entailed, and they closely adhered to the activity checklist provided within each phase.

 # 2. Three information types are vital in a learning and performance support system: Goals and Activities, Tools, and Background information

In developing the structural components within the sub-sections of "Product & Process", our primary concern was that these should contain only the necessary and sufficient elements. An additional consideration was that each distinct component should be easily recognizable and accessible as such. The distinction of the components "Goals and Activities", "Tools", and "Background information" that we developed for TOM was inspired by the Four Components model which is widely used for the (systematic) construction of software instructions (van der Meij, Blijleven, & Jansen, 2003; van der Meij & Gellevij, 2004).

The goals and activity component describes the design phase and provides students with information about the main activities therein. The goal description serves as a reminder of the main meaning of a phase. In addition, there should be information to "sell" the goal. That is, students may need to be convinced that a particular phase, and the activities therein, requires (more) time and effort than these students may do otherwise.

The tools component consists of a set of digital applications that support a particular individual or group activity (e.g., brainstorming, group communication, annotation of webpages). Just as elsewhere in TOM, each tool is introduced with a goal description that also includes the "sales argument" of the main functions that it can fulfil (see Figure 2). The inclusion of tools was considered a critical factor for the successful employment of TOM. It made TOM into a rich repository of applications that could alleviate and facilitate the students' actions during design.

The background component provided students with links to pertinent or relevant conceptual information. For instance, in the Analysis sub-section this component directed students to a website with an overview of instructional design theories to assist them in selecting the proper theory for their intervention. Students were also attended to the presence of or alternative design models to stimulate reflection on the ASCE-Model.

Time constraints prevented us from properly introducing (and using) the tools in the course parts that preceded the design task. During lectures and in the skills lab, students should have at least become acquainted with the tools that should be used during the design task. In addition, the functionality of TOM would probably have increased when we had provided more scaffolds for the usage of the three components. That is, we should have considered structuring the components in such a way that the students would immediately see the connections between a certain activity, and the available tools and background information for that activity. An additional possibility is that the checklist is not simply an undistinguished list of activities, but one that also ranks or classifies these actions. For instance, the distinction could be made between necessary, optional and additional activities.

From a theoretical point of view, there is little dispute about the functionality of an information typology for a learning and performance support system. In addition, there is agreement among researchers on the criticality of giving procedural support therein, which led us to include activities and tools. Even so, it would have been desirable to assess whether there was empirical support for this principle. Doing so would, however, have required an analytic effort that was beyond our capabilities within the TOM-development efforts.

 # 3. A learning and performance support environment is preferably all-inclusive

In setting up TOM, we have held considerable debates around the question whether or not our learning and performance support environment should be all-inclusive, aiming at providing one platform that offers all the afore-mentioned functionalities "under one roof". There were three main reasons for our final choice for inclusiveness: One, students could comfortably exchange information within and across activities, and within and across group members and even classroom participants. The all-inclusiveness probably made the students' task easier, and may also have contributed to their efficiency in completing these. Two, presenting the three main sections of Communication, Product & Process, and Report clearly conveyed home the message that these were the main tasks that students were expected to perform in the design task. Three, the chosen Learning Management Platform Moodle comfortably accommodated the presentation of all these functionalities, resources and tools in the same environment. Moodle provides an extensive list of available plugins to integrate various kinds of resources (e.g. uploading documents or linking external resources) and interactive applications (e.g. quizzes or peer feedback), and can be extended by third-party or self-developed applications. Using a web-/browser-based environment, we are following the current trend of using the internet not only as a means for communications and distribution of resources, but also as a platform for applications to be used in productive and professional contexts. Another aspect of all-inclusiveness is to provide a platform that allows access from various devices (notebook, tablet, smartphone) and from various locations (given an internet connection), thus building a basis for a flexible and seamless learning and design experience.

The usability data provided tentative support for the decision to make TOM all-inclusive. Much more so than we anticipated, students employed the tools that TOM provided for them in the Communication section. In addition, some students even explicitly expressed their liking that everything they needed to do and have for the design task was possible within the same environment.

In support of the claims for this design principle, we can state that the use of TOM was not obligatory. Students could have worked completely independent from the platform, and could have handed in their final report without ever visiting or using TOM. However, the actual usage data (i.e., the platform's activity logs) clearly shows the students' acceptance of a platform that offers communication support, productivity tools and additional information under one roof.

In conclusion, when we started the design of a digital learning and support environment we paid considerable attention to drawing up the basic requirements and constructing TOM accordingly. There was precious little time for pilot testing with the audience, and partly for this reason, we decided on creating a digital environment that was a rich smorgasbord of options. TOM would benefit from more built-in student support. Above we discussed the possibility for doing so in connecting the three key information types in the phases of the ASCE-Model. Preferably such scaffolding is informed by theory and supported by empirical evidence of its effectiveness (see e.g., McKenney, 2008; Zacharia et al., in press). Obviously, when more and more scaffolds are being added to an environment, there is a serious risk that students are hand-held too much. For instance, in real design tasks students must often prioritize task themselves, and they themselves must discover which tools are best suited for what activity. The issue of finding the proper balance between support and let-go is one of the major challenges in designing a learning and performance support environment for students. Providing students with just enough information, tools and scaffolding so that their task remains doable is, of course, also what makes our own design task interesting and challenging.

Limitations and Future Research Opportunities

Elaborating on the limitations of the presented work, three main aspects emerge: First, the number of participants has been relatively small (n=35), and they originated from a very homogenous study background (second year of the Bachelor course "Psychology"). This limits the expressiveness of the presented results - a different picture might develop when repeated with a larger number of students or with students from other disciplines. Secondly, one evaluation method was based on the analysis of student activity logs, but the recorded data may not give always a complete and correct picture: Using the TOM platform solely was not enforced; students may have used other (digital) means of communications and collaboration, and it might have occurred that two or more students were sitting at one computer when using TOM, thus the data might be distorted or not available at all. Thirdly, the design task was pre-structured by the ASCE-model for psychological interventions. Although this is a well-established model, and other models are comparable and similar, it still might have an impact on students' behavior and their evaluation of the system.

The limitations particularly question the validity of the concluded design principles. Further studies are needed to investigate the conditions under which these principles hold. Here, the mentioned limitations can be seen as a starting point to find future research opportunities, e.g. next studies should include a larger number of participants, which potentially originate from different courses who also include design tasks. Also, observing larger sets of students over a larger period of time provides more and useful data. It may be interesting to test student behavior and task results with less or more given structure, or allowing students to add interactive and collaborative tools themselves (making them create parts of their own learning support platform, much in the sense of Participatory Design practices (Kensing, 2003). This would help to derive more reliable and generalizable conclusions, and helps to refine and subtilize the presented design principles.

To conclude, this article presented an approach for the design and realization of a digital learning and performance support platform for students in the context of LBD group assignments. The described requirements, the ASCE model and the implementation in the form of an adapted, interactive and collaborative Moodle platform can build a basis for related, similar approaches; while at the same time it provides insights and groundings for further research. As mentioned in the introduction, the theoretical contribution of this paper is explorative and can help to form new hypotheses and studies in the context at hand. The three design principles, which have been elaborated earlier in this section, may stand at the core of a practical contribution from this article for the design of similar learning experiences.

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