Promoting self-regulated learning in web-based learning environments

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Abstract

Self-regulated learning with the Internet or hypermedia requires not only cognitive learning strategies, but also specific and general meta-cognitive strategies. The purposes of the Study2000 project, carried out at the TU Dresden, were to develop and evaluate authoring tools that support teachers and students in web-based learning and instruction. This paper presents how the authoring tools of the Study2000 project can implement psychologically sound measures to promote (a) active and elaborated learning activities and (b) meta-cognitive activities in a web-based learning environment. Furthermore, it describes a study involving 72 university students in the use of such a web-based learning environment in a self-regulated learning setting at the university level. Results show that students spent almost 70% of their study time with texts, 11% with learning tasks and 12% with the active and elaborated learning tools, whereas meta-cognitive aids where hardly used (<1%).

Keywords: Self-regulated learning; Web-based learning environments; Learning strategies

1. Promoting self-regulated learning in web-based learning environments

The Internet is an open information system in which various sources of information, media and materials (i.e., texts, images, video sequences) can be linked together in diverse ways to form so-called hypertext or hypermedia environments. Thus, it offers new possibilities to structure, represent, adapt and integrate various learning content and
materials. Furthermore, due to its interactivity, learners can process the material in accordance with their individual preferences and strategies at any time and from any place provided an internet connection is available. They may select and examine from a large pool of information only those pieces necessary to meet their learning objectives. Hence, the potential of the Internet as an instructional hypermedia system is considered to be very high.

However, the universal access to multiple sources of information as well as the non-linear structure and interactivity of open information systems create additional demands on learners in all phases of the learning process; the amount and structure of the learning materials can pose learners great difficulties. Various connections between materials from different sources of information need to be established. These various sources of information have to be located, examined and evaluated. This process involves risks due to the non-linearity of web-based documents and the learner’s own knowledge deficiencies with regard to content and strategy.

Among such risks are the flood of information, incoherency of some of the documents provided, inconsistency of technical functions and attractive, yet psychologically unsound multimedia applications (see also Mayer & Moreno, 2002; Rouet & Levonen, 1996). Thus, learners might be distracted from their learning objectives or lose their way in hyperspace; they may work on too much irrelevant information or only consume important information cursorily (e.g., Salomon & Almog, 1998). Some may not even start the learning activities as taking even the first step onto this “mountain of information” can be perceived as an insurmountable task. Hence, even though web-based learning environments provide approaches to self-regulated learning (e.g., problem-based learning, blended learning, project-based learning), they impose numerous new demands on learners. Moreover, research on self-regulated learning reveals that learners are often not able to cope with these demands (e.g., Pressley & Ghatala, 1990; Simons & de Jong, 1992).

Efficient learning is only guaranteed if learners actively engage in processing learning material. The most important task instructional designers and teachers have to solve is to develop strategies which encourage, prime and guide learners in actively processing the web-based material (e.g., Mayer, 2003; Mayer & Moreno, 2002). In the Study2000 project, we developed generic authoring tools to support designers and teachers in mastering these important instructional tasks. These authoring tools permit the creation of web-based learning environments which provide several study tools for fostering learner’s active information processing in web-based learning (Narciss & Körndle, 1998, 1999, 2001; http://studierplatz2000.tu-dresden.de).

The purposes of this paper are to (a) present psychologically sound approaches to promoting self-regulated learning with web-based learning environments, (b) illustrate how instructional designers/teachers can integrate such approaches to foster self-regulated learning into web-based learning environments with the tools of the Study2000 project and (c) report the results of a study on how students use such a web-based learning environment in a self-regulated learning setting.

2. Challenges of self-regulated web-based learning

An important prerequisite to the promotion of self-regulated multimedia learning is the awareness of essential challenges. Based on a wide body of psychological research, the present analysis aims to attract attention to important factors contributing to the high
demands of self-regulated learning with web-based learning environments (e.g., Boekaerts, 

Self-regulated learning refers to a learning situation in which learners, in addition to setting 
their learning objectives, plan, conduct, regulate and evaluate the learning process 
independently (Boekaerts, 1997, 1999; Zimmerman, 2001). Consequently, they must master 
a large number of demands, for example preparing learning activities which match 
their learning objectives, conducting and monitoring these activities as well as searching 
for feedback on their learning progress (Winne, 2001; Winne & Hadwin, 1998). Coping 
with these demands efficiently requires not only task or content-related cognitive strategies, 
but also specific meta-cognitive strategies, such as the selection and activation of 
appropriate learning and working strategies. Furthermore, the independent management 
and regulation of learning processes require the application of general meta-cognitive 
strategies which enable the learner to monitor and regulate the learning process (e.g., 

Hypermedia systems, such as the Internet, impose additional demands due to (a) the 
 excessive amount of information available, (b) their non-linear structure and (c) technolog-
ical inconsistencies and limitations. Table 1 represents a summary of general and 
media-specific requirements related to self-regulated learning with multimedia. These 
requirements refer to the phases of the learning process, as well as the different levels of 
cognitive and meta-cognitive strategies.

A further factor should also be taken into consideration. Attractive multimedia plat-
forms containing, for example, interesting but irrelevant material, can tempt learners to 
consume the presented information passively and superficially (coherence principle, see 
Mayer, 2001). Moreover, the computer as a medium itself induces a more trial-and-
error-like behavior as opposed to problem or goal-oriented behavior. Indeed, studies on 
the “lost-in-hyperspace” phenomenon reveal that learners tend to “skip” between the doc-
uments of a hypermedia system without respecting their semantic or logical relations (e.g., 
Rouet, 1990; Rouet & Levonen, 1996; Salomon & Almog, 1998). Ignoring these relations 
makes learning and comprehension much more difficult and results in inefficient learning 
activities. Hence, in order to monitor and regulate their learning processes, learners must 
develop special strategies and heuristics. In other words, they have to evolve a meta-
strategy.

Concerning the evaluation of learning processes, it is of essential importance to mon-
itor learning activities and their separate phases (Pintrich, 2004), and if necessary, ask 
for (external) feedback (e.g., Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). A large 
number of computer-based learning systems offer task or question modules for evaluat-
ing the learning process (Hoskins & van Hooff, 2005; Nadolski, Kirschner, & van Mer-
riënboer, 2006). However, the absence of such modules, for instance in open, networked 
information systems, requires learners to develop certain strategies to specify their learn-
ing objectives in such ways that they can be used as criteria for examining learning success.

In addition to the above-mentioned cognitive and meta-cognitive demands, self-reg-
ulated learning also imposes high demands on the regulation of motivation and attention 
(cf. Boekaerts, 1997). Motivational factors determine, for example, the tasks 
selected and effort invested in solving them. Furthermore, they are especially important 
if learners encounter hurdles whose successful mastering requires (additional) learning activities.
Table 1
Overview on requirements of self-regulated learning through web-based hypermedia systems

<table>
<thead>
<tr>
<th>Levels of cognitive regulation</th>
<th>Phase of the learning process</th>
<th>Process</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General, meta-cognitive requirements</strong></td>
<td><strong>Preparation</strong></td>
<td>Setting goals and specifying sub-goals</td>
<td>Monitoring and regulating learning activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• What do I know already?</td>
<td>• Is the selected material useful?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• What do I want to know?</td>
<td>• Have I chosen an appropriate learning strategy?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Which organizational constraints have to be taken into account?</td>
<td>• How can I overcome obstacles?</td>
</tr>
<tr>
<td><strong>Specific meta-cognitive requirements</strong></td>
<td><strong>Process</strong></td>
<td>Selecting and activating learning strategies</td>
<td>Planning the evaluation of the learning progress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• What learning strategies are relevant?</td>
<td>• How can learning goals be transformed into criteria for evaluating learning outcomes?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• When and how can I use these learning strategies?</td>
<td>• Are there any tests for the given domain of knowledge?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• How do I cope with material and media for which I do not know a learning strategy?</td>
<td>• Are there any case studies to check knowledge transfer?</td>
</tr>
<tr>
<td><strong>Task and content-related cognitive requirements</strong></td>
<td><strong>Evaluation</strong></td>
<td>Planning the learning process</td>
<td><strong>Retrieving and applying acquired knowledge</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• What sources of information are relevant for the goals?</td>
<td>• How can I obtain external feedback?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Where can I find these sources?</td>
<td>• Answering questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• How long does it take to obtain material from these sources?</td>
<td>• Solving learning tasks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Working on case studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Transferring feedback</td>
</tr>
</tbody>
</table>

Research in the field of self-regulated learning reveals that many learners fail to control and regulate their learning activities with hypermedia systems due to a deficit in the skills necessary to comply with the above-mentioned demands (see e.g., Azevedo, 2002; Chen & Rada, 1996; Dillon & Gabbard, 1998; Simons & de Jong, 1992). An analysis of the challenges posed by self-regulated hypermedia learning shows that various instructional interventions are necessary to promote learning with hypermedia systems. These can be developed and examined for the various phases of the learning process, taking into consideration different cognitive and meta-cognitive strategies.

Hadwin, Winne, and Nesbitt (2005) identified two broad categories of instructional interventions: (a) tools that deliver instruction and (b) tools that guide and tutor learning. According to Friedrich and Mandl (1997) the first might also be referred to as direct interventions and the second as indirect interventions. These interventions can be either embedded or non-embedded in the learning environment (Clarebout & Elen, 2006).

Embedded instructional interventions are integrated in the learning environment and thus learners are forced to consider them. Meta-cognitive guiding, such as regularly prompting monitoring strategies (e.g., Winne & Stockley, 1998; Bannert, 2004) is an example of an embedded direct intervention. Orientation and navigation support, such as giving a well-structured overview of the available documents in the form of a hierarchically organized table of contents (e.g., Dee-Lucas, 1996; Rouet & Levonen, 1996) can be considered an embedded indirect instructional intervention.

The use of non-embedded instructional interventions is dependent on the learner’s initiative. These instructional interventions are provided within the learning environment, but the learners can decide to use them or not. As such, self-regulated learning with hypermedia can be promoted with non-embedded indirect interventions such as psychologically sound active learning tools, for example, highlighting or note-taking facilities (van Oostendorp, 1996). Furthermore, learning tasks of varying complexity can support the monitoring and evaluation of learning progress and represent likewise a non-embedded indirect intervention (see Proske, Körndle, & Narciss, 2004).

Providing informative tutoring feedback (Narciss, 2004, 2006) within these learning tasks is a non-embedded combination of a direct and indirect intervention. Informative tutoring feedback provides strategically useful information that stepwise guides the learner towards successful task completion, thereby assisting multiple solution attempts. On the one hand, informative tutoring feedback delivers instruction to solve the task successfully; on the other hand the information provided guides and tutors the learning process. Furthermore, learners have to act in order to receive these instructions: they have to work on a task and, in case of a mistake, mindfully use the provided informative feedback information.

In the Study2000 project we developed, implemented and evaluated generic authoring tools to facilitate the ergonomically and psychologically sound design of web-based learning environments (see http://studierplatz2000.tu-dresden.de). These tools include:

- The s2w-compiler (Study-to-Web Compiler), which supports instructors in combining and integrating multiple learning materials and media into an integrated interface which provides direct and efficient access to all materials and media (accessible at: http://studierplatz2000.tu-dresden.de/s2w).
The EF-Editor (Exercise Format Editor) authoring tool, which facilitates the construction and implementation of interactive learning tasks (for a detailed description see Proske et al., 2004; http://studierplatz2000.tu-dresden.de/efb). In contrast to test exercises, interactive learning tasks are solved interactively with the additional aid of multiple-try strategies and informative tutoring feedback if required (Narciss, 2004, 2006; Narciss & Huth, 2004).

We call a web-based learning environment designed with these authoring tools Studierplatz (in English: Study Desk), that is, a working space for learning and studying. In contrast to web-based learning components which deliver isolated content, Study Desks are designed to complement instruction in different learning contexts, such as lectures, seminars or project-based courses. They present multiple materials and information on a specific topic. Thus, students are not only able to prepare for lessons, but also repeat and elaborate knowledge in a self-regulated manner. A Study Desk employs the following instructional interventions to promote self-regulated learning in a hypermedia environment:

- embedded indirect intervention orientation and navigation support;
- non-embedded indirect intervention tools for active and elaborated learning – learning tools and elaboration resources;
- non-embedded indirect intervention tools for monitoring and evaluation – monitoring tools and interactive learning tasks;
- non-embedded combined intervention informative tutoring feedback.

3.1. Orientation and navigation – the Study Desk-interface

A Study Desk offers access to various learning materials (e.g., texts, transparencies, experiments, exercises, WWW-links and references). To support orientation and navigation, students should be informed: (a) of their current location within the learning environment and the steps they have taken to reach this location; (b) which parts of the learning environment they have already processed and in which way they can process information; and (c) which additional information sources are available (Conklin, 1987). More specifically, the Study Desk-interface offers the following information (see Fig. 1):

1. Information on the content structure is offered by a hierarchically structured table of contents. As scientific topics tend to be complex, this table of contents is presented in such a way that at first only the main chapters are indicated, thus offering a general overview. A mouse click on one of the entries gives a detailed view of its respective sub-chapters.
2. A running-title line above the actual working area gives information on the current (sub-)chapter.
3. Labeled user buttons in the bottom frame of the screen provide information on the availability of multiple multimedia resources (e.g., references, links to relevant webpages, videos, learning tasks, labelled here exercises). The button is blue if a resource is available in the current chapter and grey if unavailable.
4. Information on monitoring learning activities is presented in the table of contents by means of indicating already treated chapters and is additionally provided in the form of a progress protocol which offers an overview on all running and accomplished learning activities (see also Fig. 3).

In terms of the overview in Table 1 offering this information aims at supporting the planning and monitoring of the learning process, and the efficient processing of learning materials.

3.2. Active elaborated learning – active learning and elaboration tools

Active, elaborated information processing is an important condition for the efficient and successful acquisition of knowledge from a cognitive view (see Lockhart & Craik, 1990 for a summary). However, as mentioned above, learners employ activities such as surfing, scanning, and trial-and-error-like exercise completion more often than activities of deep information processing in attractive multimedia learning environments. In order to counter these superficial learning activities, a Study Desk provides tools for active learning and elaboration which enable learners to mark certain sections, make notes and integrate material they consider to be of interest or importance into an individual dossier. These tools permit the application of widely-used conventional study methods with which the students are familiar.

Fig. 1. Interface of a Study Desk – navigational support.
The learning tools can be activated by clicking on the related buttons in the bottom frame of the screen. To highlight interesting or important words, sentences, paragraphs or pictures, the learner activates the marking tool, chooses a color, clicks on the first word or element of interest, and then clicks on its last word or element. Consequently, the space between these words or elements is highlighted in the selected color. When taking notes, the learner activates the note-taking tool, clicks on the word or element of the working space referring to the intended note and writes the note into the note-taking window. These notes are saved and flagged in the working space by a small yellow tag (see Fig. 2). To document and organize material, learners activate the integrator tool and save all materials they consider important (e.g., transparencies, web sites, pictures, etc.) with their individual notes to an individual dossier, which can play the collected material in a slide-show. Furthermore, learners have constant access to a glossary containing the relevant terms of the corresponding Study Desk, their definitions and synonyms.

Elaboration resources provide additional information about the subject of the corresponding Study Desk. In addition to the learning text, Study Desks provide audio-visual materials such as lecture transparencies, videos and experiment simulations. Various commented Internet resources as well as references, suggested readings and original research papers are made available so that learners have the opportunity to process information on the particular topic from various perspectives.

Fig. 2. Tools for active, elaborated learning integrated into Study Desk.
3.3. Monitoring and evaluation – learning tasks with feedback, progress report

Monitoring and evaluating the learning progress are essential for successful self-regulated learning (Boekaerts, 1999; Pintrich, 2004). Study Desk supports monitoring by offering access to the protocol of all learning activities (progress and task report). Thus, learners may check which chapters they have already completed, the amount of material and media still at their disposal as well as the number of accomplished and unaccomplished learning tasks (see Fig. 3).

A core component for fostering learners’ evaluation is an interactive learning task module containing multiple tasks of diverse complexity together with informative tutoring feedback and/or tutoring instructions (e.g., Nadolski et al., 2006).

The term informative tutoring feedback (ITF) refers to feedback types which provide strategically useful information for successful task completion (Narciss, 2004, 2006). ITF applies a combination of program and learner control. The strategic information is presented so as to tutor students in detecting errors, overcoming obstacles and applying more efficient strategies towards solving learning tasks. After learners fail on the first response of a learning task, the program delivers immediate feedback indicating a mistake has been made. They then receive a prompt to use available hint information (program control). To receive this information, the learners have to take action, that is, they click on the button “hint” (learner control). After the next incorrect attempt the system (a) gives an evaluation of the overall performance and (b) marks correctly
answered parts of the question green, while incorrectly answered question parts are labeled red. Again the learner is prompted to use the hint information. Hence, working on interactive learning tasks may enable learners to find knowledge gaps, correct mistakes and regulate the further learning process independently (Gao & Lehman, 2003). Fig. 4 illustrates an interactive learning task with ITF-components created with the EF-Editor.

4. How students use Study Desk tools

We conducted a study examining if and how students use the learning tools offered by Study Desk. Its main purpose was to investigate to what extent we succeeded with the above-described tools in initiating task and content-related learning activities (marking, note-taking and elaboration) and meta-cognitive activities (monitoring and evaluating the learning process and outcomes).

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1 For interpretation of the references in color in Fig. 3, the reader is referred to the web version of this article.
4.1. Method

4.1.1. Participants
Ninety-one university students of an introductory lecture to general psychology participated in the study. Most participating students were in their second year of studies. As some students worked less than 5 min and others encountered technical problems with the Study Desks, a total of 72 individual log-files could be used for data-analyses (48 women, 24 men; mean age 22; SD = 2.4).

4.1.2. Material and procedure
Students had 5 Study Desks on different learning theories at their disposal over the period of one university semester. The contents of these Study Desks complemented the learning theories curricula of the introductory lecture to general psychology (see Table 2).

The successful completion of the course required students to pass a test at the end of the semester. Students were free to work on the 5 Study Desks as many times and as long as desired. Furthermore, there were no restrictions regarding the learning objectives and the selected topics. Hence, students had to self-regulate their learning activities with the 5 Study Desks.

4.1.3. Measures
Each time students worked with a Study Desk they logged in with an individual user name and password, meaning that for each student all learning activities were program-tracked in an individually coded log-file. Frequency and time of each learning activity were automatically summarized in each log-file. The measure of total working time represents the sum of time on all learning activities. Yet, there was a high variability in the amount of available material in the 5 Study Desks (see Table 2), the selection of the Study Desks and the time spent on the selected Study Desks. In order to account for these differences, the measure of time on a particular learning activity was standardized using percentages. As such, the time on a particular learning tool, elaboration resource or monitoring tool is expressed as percentage of total working time (% time-on-text; % time-on-learning tasks; % time-on-tools for active learning and elaboration; % time-on tools for monitoring and evaluation).

All interactive learning tasks implemented in the Study Desks provide multiple-try strategies and informative tutoring feedback information. Informative tutoring feedback

<table>
<thead>
<tr>
<th>Topic of the Study Desk</th>
<th>Main chapters</th>
<th>Text pages</th>
<th>Learning tasks</th>
<th>Elaboration resources</th>
<th>Students</th>
<th>Logins</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to learning theories</td>
<td>3</td>
<td>17</td>
<td>21</td>
<td>61</td>
<td>58</td>
<td>2.74</td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td>Classical conditioning</td>
<td>5</td>
<td>28</td>
<td>42</td>
<td>30</td>
<td>50</td>
<td>2.94</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>Operant conditioning</td>
<td>9</td>
<td>136</td>
<td>75</td>
<td>128</td>
<td>47</td>
<td>2.70</td>
<td>2.53</td>
<td></td>
</tr>
<tr>
<td>Purposive behaviorism</td>
<td>4</td>
<td>26</td>
<td>16</td>
<td>9</td>
<td>30</td>
<td>2.23</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Socio-cognitive theory of learning</td>
<td>4</td>
<td>15</td>
<td>26</td>
<td>27</td>
<td>40</td>
<td>2.58</td>
<td>2.17</td>
<td></td>
</tr>
</tbody>
</table>
guides the learner towards successful task completion. In order to assess the quality of students’ learning activities while working with the 5 Study Desks the percentage of correctly solved learning tasks in a first attempt was taken as a performance measure. This performance measure represents the number of correctly solved learning tasks related to the number of learning tasks students had at their disposal within their selected Study Desks.

Finally, students’ perceived acceptance regarding the work with the Study Desks was measured by a shortened version of the Isometrics (Gediga, Hamborg, & Düntsch, 1999). All students who worked at least 30 min with the Study Desks were asked to answer 20 items on a rating scale ranging from 1 (=I do not agree at all) to 6 (=I agree completely). These items addressed usability features such as ease of learning, efficiency of use, memorability and controllability, error frequency and severity and subjective satisfaction (Cronbach’s $\alpha = 0.92$). Furthermore, students had the opportunity to leave open comments and feedback on usability.

4.2. Results

The number of students who worked with each Study Desk and the frequency of their use were analyzed first. As indicated in Table 2, 80% of the students worked with the introductory Study Desk, 65–69% with the Study Desks on conditioning, 55% with the Study Desk on the socio-cognitive theory of learning and 42% used the purposive behaviorism Study Desk. The mean number of individual logins per Study Desk varied between two and three.

4.2.1. Total working time

The analysis of total working time revealed a large variability in the time students spent studying with the Study Desks ($M = 194.5$ min, $SD = 229.9$). Some students spent only a few minutes while others worked for hours. Due to the high variability the sample was divided into three percentiles by means of total working time for analysis of students’ learning activities:

(a) 23 students working less than 40 min (<40 group) ($M = 18$ min, $SD = 10.1$);
(b) 25 students working between 40 and 180 min (40–180 group) ($M = 87$ min, $SD = 39.5$);
(c) 24 students working more than 180 min (>180 group) ($M = 475$ min, $SD = 188.0$).

4.2.2. Learning activities

An analysis addressing the question of the amount of time the students of these three groups utilized the tools for elaborated learning provided the results represented in Table 3. Students of all groups spent most of their total working time in processing learning texts (65.3–72.4%). Learning tasks were processed within 7.2–15.1% of the total working time. A Kruskal–Wallis test provided evidence that the differences in the relative time on task processing between the three groups are statistically significant ($\chi^2(2, 72) = 8.89; p = 0.01$). Students of the >180 group spent significantly more time on task processing than students of the other groups (see Table 3).
The tools for active learning were used within 6.1–10.1% of the total working time. As represented in Table 3, the marking tool was used more often than the note-taking tool, the glossary or the integrator. It is worth noting that the >180 group spent significantly more time querying terms in the glossary than the other groups ($\chi^2(2, 72) = 5.97; p = 0.05$). The percentage of time on elaboration resources varied between 2.7% and 5.8%. As indicated in Table 3, WWW-links, transparencies and videos were used by some students. However, the experiments and original research papers were hardly used. The same is true for the monitoring tools.

### Table 3
Descriptive statistics for learning activities for three groups of students

<table>
<thead>
<tr>
<th>% Time on learning activity</th>
<th>Groups defined by working time in minutes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;40</td>
<td>40–180</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Total working time</td>
<td>17.8</td>
<td>5.6</td>
</tr>
<tr>
<td>Text processing</td>
<td>65.3</td>
<td>27.1</td>
</tr>
<tr>
<td>Learning tasks processing</td>
<td>11.6</td>
<td>23.6</td>
</tr>
<tr>
<td>% Time on learning tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Marking</td>
<td>6.1</td>
<td>11.5</td>
</tr>
<tr>
<td>• Note-taking</td>
<td>2.4</td>
<td>7.2</td>
</tr>
<tr>
<td>• Glossary</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>• Integrator</td>
<td>1.1</td>
<td>4.3</td>
</tr>
<tr>
<td>% Time on elaboration resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• WWW-links</td>
<td>5.8</td>
<td>11.4</td>
</tr>
<tr>
<td>• Transparencies</td>
<td>1.1</td>
<td>3.3</td>
</tr>
<tr>
<td>• Videos</td>
<td>1.2</td>
<td>3.3</td>
</tr>
<tr>
<td>• Experiments</td>
<td>3.6</td>
<td>8.0</td>
</tr>
<tr>
<td>• Research papers</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% Time on monitoring tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Progress report</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>• Learning task report</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>• Material overview</td>
<td>1.4</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Note: Time spent on technical help functions and on questionnaires is not listed here.

- $<40$ min = 23 students working less than 40 min with the 5 Study Desks; 40–180 min = 25 students working 40–180 min with the 5 Study Desks; >180 min = 24 students working more than 180 min with the 5 Study Desks.

b Measures represent percentages of the total working time.

* $p < 0.05$.

** $p < 0.01$.

The tools for active learning were used within 6.1–10.1% of the total working time. As represented in Table 3, the marking tool was used more often than the note-taking tool, the glossary or the integrator. It is worth noting that the >180 group spent significantly more time querying terms in the glossary than the other groups ($\chi^2(2, 72) = 5.97; p = 0.05$). The percentage of time on elaboration resources varied between 2.7% and 5.8%. As indicated in Table 3, WWW-links, transparencies and videos were used by some students. However, the experiments and original research papers were hardly used. The same is true for the monitoring tools.

#### 4.2.3. Quality of learning activities – performance

The number of processed texts and learning tasks were analyzed in greater detail as students spent the most time carrying out these activities (see Table 4). This revealed that the >180 group processed 58.4% of the texts, while the 40–180 group and the <40 group processed 35.4% and roughly 24% of the texts, respectively. These differences are statistical significant ($\chi^2(2, 72) = 22.1; p < 0.01$).

By analyzing the number of learning tasks students processed related to the number of learning tasks students had at their disposal, it was found that the >180 group worked on 23.8% of the learning tasks, whereas the students of the other groups worked on approximately 5% of the available tasks ($\chi^2(2, 72) = 13.20; p < 0.01$). Furthermore, the >180 group
solved 21.1% of the tasks correctly, whereas the students of the <40 group and the 40–180 group correctly solved only 3.2% and 4.0% of the tasks, respectively ($\chi^2(2,72) = 10.08; p < 0.01$). Kruskal–Wallis tests reveal that these differences are statistically significant. It is worth noting that the relative ratio of correctly solved tasks is also higher for the >180 group (66.8%) than for the 40–180 (59.9%) and <40 groups (52.4%) even though one might expect that working on more tasks makes it more likely to make errors.

To analyze how tool-use was related to learners’ performance, we conducted a correlation analysis for those subjects of the >180 group who had worked on learning tasks ($n = 17$; for the two other groups a correlation analysis was not reasonable because only $n = 6$ students of the <40 group and $n = 8$ of the 40–180 group worked on learning tasks). This correlation analysis yielded only two significant correlations: first, time-on learning tasks and performance was positively correlated ($r = 0.54$, $p < 0.05$), second, time-on glossary and performance was negatively correlated ($r = -0.51$, $p < 0.05$).

4.2.4. Acceptance

Perceived acceptance was assessed after working for at least 30 min with the Study Desks. However, some technical difficulties in providing the acceptance questionnaire were experienced. Hence, only four students of the <40 group ($M = 4.44$, $SD = 0.60$), 14 students of the 40–180 group ($M = 3.88$, $SD = 0.76$), and 23 of the >180 group ($M = 4.06$, $SD = 0.95$) received this questionnaire and were able to answer it ($n = 41$). All students rated the usability of the Study Desks as rather high ($M = 4.03$, $SD = 0.86$). The open comments also reflected a rather high usability of the Study Desk-Interface. However, the students would have liked to have additional paper versions of the texts and tasks at their disposal.

5. Discussion

This article described the implementation of instructional interventions into a web-based learning environment, known as Study Desk. The instructional interventions implemented,
either embedded, non-embedded (Clarebout & Elen, 2006), or a combination of embedded and non-embedded tools, should foster self-regulated learning in web-based learning environments.

The results of our study show that there is a high variability in total working time. Whereas some students studied for only a few minutes, others spent more than 7 h with the Study Desks. However, the results of the analysis of students’ learning activities when studying with the 5 Study Desks indicate that students employ relatively the same learning strategies in web-based learning environments as they do with printed textbooks. On average, students spent 70% of their total working time with processing texts. They spent a maximum of 15% of total working time processing learning tasks and a maximum of 13% of total working time using the active learning and elaboration tools. Only a very small number of students used the monitoring tools. Furthermore, only a few students used the experiments, whereas the possibility of downloading original research papers was not used at all.

Within the time students spent with the 5 Study Desks, students who worked more than 3 h processed, on average, 58% of the available texts and 24% of the available learning tasks. Furthermore, they succeeded in solving 21% of the learning tasks correctly. Moreover, the more time students worked on learning tasks the higher their performance. Students working less than 3 h processed a significantly lower percentage of texts and tasks and achieved significantly poorer scores. Despite the variability in total working time, performance and time spent with different learning activities all students rated the usability of the Study Desks as rather high.

There might be several reasons accounting for the minimal use of the active learning, elaboration and monitoring tools. First, the given instructional context (i.e., an introductory lecture with optional, complementary web-based learning) may be associated in particular with text processing. However, for university students one would have wished that they had used the tools providing original experiments and research papers, in order to elaborate the material presented in the main lecture. Furthermore, the large amount of material in the 5 Study Desks would have required the application of meta-cognitive activities such as planning, monitoring and evaluating their learning activities. Unfortunately, the present data do not explain why these tools remained virtually unused. Thus, future research should address this issue.

Second, the participants of the study were in their second year of study. Consequently, the majority of their prior lectures were at an introductory level. Hence, the students may not have had the opportunity to develop strategies for active elaborated knowledge construction and self-regulation. Furthermore, inexperienced learners might not be able to translate their usual learning behavior into efficient web-based learning activities (see also Seufert, Jänen, & Brünken, 2006). In order to protect such students from being overloaded by the demands of efficient self-regulated web-based learning, they could be persuaded to use the provided tools by direct interventions (Kester & Paas, 2005). While such direct interventions are useful for inexperienced learners, they can hinder the learning process of those with greater experience. Thus, future research should, on the one hand, focus on comparing students’ usual study strategies and learning activities with those in web-based learning. On the other hand, it should answer the question of how direct intervention of a web-based learning environment can be adapted to the level of learners’ expertise.

Third, the quality of the available texts, the quality of the Study Desk-interface, and the technical quality of the specific tools may have contributed to the present results: (a) The
texts presented in the Study Desks were developed respecting guidelines for writing comprehensive web-based texts. Each web-based text unit was thus concise, coherent and easy to understand. Perhaps some students considered it unnecessary to highlight or to make notes. (b) As described above, the Study Desk-interface provides information on which chapters and learning tasks had been processed by marking the processed chapters and tasks. The specific monitoring of text and task processing is thus possible without using the progress or learning task reports. Thus, the minimal use of the monitoring tools does not reveal if students engaged in specific meta-cognitive activities or not. It does, however, indicate that students did not engage in general meta-cognitive activities (e.g., planning, monitoring and evaluating learning activities within the available time). General meta-cognitive activities can only be applied if one checks the overall amount of available material, the amount of successfully treated material, as well as the material remaining to be processed. (c) There were several technical limitations in applying the tools which provide access to audio-visual material and media (e.g., videos, experiments, and WWW-links). The efficient usage of these tools required a fast and powerful Internet access. However, not all students had such an Internet access. Whereas these technical limitations might explain why only a few students used these elaboration tools, they do not explain the reason the monitoring tools and the tool for downloading original research paper remained virtually unused.

An important issue related to the disappointing result that students left the non-embedded intervention tools unused is the question of how to prepare web-based learning environment users for self-regulated learning with Internet resources. The issue is not only limited to non-embedded intervention tools as it can also be argued that even embedded direct interventions can be ignored or processed superficially by the students (cf. Aleven, McLaren, & Koedinger, 2006). Prior research on self-regulated learning with computer-aided instruction shows that direct and indirect instructional interventions should be combined in order to foster self-regulated learning both with and without modern information technologies (e.g., Simons & de Jong, 1992; Winne & Stockley, 1998). Furthermore, investigations should be carried out to determine (a) which tools are appropriate for attaining specific learning goals and (b) the conditions under which learners consult these tools (see Clarebout & Elen, 2006; see also Munneke, Andriessen, Kanselaar, & Kirschner, 2006).

Another issue for future research and practice is the question of how individual variables may determine the way students learn with web-based learning environments. Studies on cognitive and personality variables reveal that academic ability and attitude (e.g., Hiltz, 1993), multimedia comprehension skill (Maki & Maki, 2002) and openness to experience (Maki & Maki, 2003) are significantly related to performance when learning with web-based learning environments. Furthermore, a study of Joo, Bong, and Choi (2000) provided insight into the role of self-efficacy in web-based learning performance. However, to date there has been little research into how individual differences in learning strategies and styles, learners' goals and motivational orientations and learners' meta-cognitive skills contribute to differences in studying in web-based learning environments. Certainly, these issues deserve further investigation.

Moreover, in the present study, Study Desks fostered the coverage of general, meta-cognitive requirements (e.g., monitoring and regulating learning activities, evaluating learning progress; see Table 1) as well as task and content-related requirements (e.g., processing learning material and media, retrieving and applying acquired knowledge; see Table 1).
Tools that foster specific meta-cognitive requirements, such as planning learning process or selecting and activating learning strategies, were not included. Thus, future studies should investigate if the integration of planning and goal setting tools, in which students can determine their own learning activities independently, enhances the use of active learning, elaboration and monitoring tools.

References


