Educational Technology Expertise Center
Open University of the Netherlands

Research project proposal

This project falls in the following research topic(s):

Tasks
- Domain specific competence development
- Learner guidance & support
- Assessment of complex performances

Environments
- Domain specific competence development
- Learner guidance & support
- Assessment of complex performances

Communities
- Domain specific competence development
- Learner guidance & support
- Assessment of complex performances

1 Candidate
Liesbeth Kester

2 Project title
English: Scaffolding the usage of task-related information during cognitive skill acquisition in powerful learning environments.
Dutch: Ondersteuning van het raadplegen van taak-gerelateerde informatie tijdens het verwerven van cognitieve vaardigheden in krachtige leeromgevingen.

3 Place in the organization
This project is part of the OTEC research program (2004-2008).

4 Synopsis of the research problem
The acquisition of cognitive skills by problem solving in powerful learning environments is hampered by the fact that learners have difficulty in determining their information needs. They do not know what they do not know. This is primarily due to the fact that their perception of problem demands is often insufficient (i.e., they have difficulty to determine all relevant problem aspects). Furthermore, novices in a domain do not have a good impression of what there is to know about a particular problem. Therefore, they cannot determine which information might help them to complete the task at hand. Aim of this research is to find out if different types of scaffolding (i.e., demand-perception scaffolding to support the perception of task demands and conceptual scaffolding to give a domain impression) help learners to determine their information need and whether this has beneficial effects on the learning outcome.

5 Research team

<table>
<thead>
<tr>
<th>Name and titles</th>
<th>Expertise/function</th>
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<tbody>
<tr>
<td>a Chair</td>
<td>Dr. Liesbeth Kester</td>
<td>OTEC</td>
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<tr>
<td>Co-writers</td>
<td>Prof. dr. Jeroen van Merriënboer</td>
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<td>Prof. dr. Paul Kirschner</td>
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<td>Senior educational technologists</td>
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10 Length of the project
Begin date: June 2004
End date: June 2005
Total length: 1 year (0.15 fte)

11 Intended output
a Publications and conference presentations (short dissemination plan with splitting up between scientific and non scientific publication)
Scientific publications:
Article 1: Literature review + pilot study
Article 2: Experiment
Conference presentations:
ORD 2005
EARLI 2005

b Instruments and procedures
This project will result in effective scaffolding methods that help learners determine their information needs during cognitive skill acquisition by (authentic) problem solving in powerful learning environments.

12 Further elaboration
a Further elaboration of the problem and aims of the research project, including scientific framework
In powerful learning environments rich information resources are offered during authentic or realistic task practice to help learners acquire cognitive skills or competencies. These learning environments allow learners to learn from their own interactions with the information resources during problem solving or task execution. Learners are, thus, actively involved in using these resources (Hannafin, Land & Oliver, 1999). Although, the information resources can take many forms (e.g., video, audio, simulation, text) the focus here is on text-based material such as (study)books or manuals and on-line help. When confronted with a (authentic) learning task, learners have to take several steps to retrieve, from the available text-based resources, the information they need to carry out the learning task. First, they have to define the problem provided in the learning task and identify the information requirements. Second, they have to determine the range of sources and prioritize these sources. Third, they have to locate the sources and find the information. Fourth, they have to extract and use the information. Fifth, they have to organize and present the information and finally, sixth, they have to judge the product and judge the process. These six steps a learner has to take to find and use the information necessary to carry out the learning task are referred to as the Big6 skills for information problem-solving (Eisenberg and Berkowitz, 1990). In this research project the focus is primarily on the first step 'define the problem provided by the learning task and identify the information requirements' or, in other words, on 'the formulation and analysis of information need' (Irving, 1985).

The information that is required to carry out the learning task and acquire the cognitive skill consists of two qualitatively different types. First, supportive information, such as, domain models or Systematic Approaches to Problem-solving (SAP's) is necessary. This information enables the learners to construct general, abstract schemata through elaboration, that is, the supportive information is gradually coupled to already existing, relevant cognitive schemata in long term memory. During practice these cognitive schemata are modified and refined, resulting in more appropriate schemata given the experiences. This process is called induction (Proctor & Reeve, 1988; Holland, Holyoak, Nisbett, & Thagard, 1986). Elaboration and induction of supportive information yields cognitive schemata that contain general knowledge, which is particularly useful when learners have to deal with unfamiliar task aspects.
Second, *procedural* information, such as, task specific rules along with the facts, principles, or concepts needed to correctly apply these rules is necessary. This information enables the learners to form specific schemata or production rules through knowledge compilation, that is, the compilation of declarative knowledge, either from long-term memory or from the outside world, into procedural knowledge. After compilation, further practice causes these specific, compiled schemata to gain strength every time they are successfully applied during practice. This process is called strengthening (Anderson, 1996; Anderson, 1982). Knowledge compilation and strengthening of procedural information yield automated schemata that contain specific knowledge which is particularly useful when learners have to deal with familiar task aspects.

To formulate and analyze their information need related to a learning task learners first have to properly perceive the task demands in order to define the problem that is provided by the task. Subsequently, they can decide what supportive or procedural information is necessary to meet these task demands and to do that they must have a notion of what there is to know with regard to the particular problem. So, to determine their information need learners need a proper perception of the task demands and a proper impression of the problem domain (Butler & Winne, 1995; Nist & Simpson, 2000; Thomas & Rohwer, 1986).

Research shows that properly perceiving the task demands is often problematic for learners (Broekkamp, 2003). A proper perception of task demands is dependent on the information that is provided with regard to the task demands and the way learners use this information to develop their perception of the task demands (Broekkamp, van Hout-Wolters, Rijaarsdam, & Van den Bergh, 2002). In his studies, Broekkamp (2003) compared student expectations concerning important text sections (content demands) and types of test questions (processing demands) to the actual test demands and he found considerable discrepancies between them. Apparently, students were not able to effectively use the provided task information to develop a proper perception of the task demands. A causal relation between a student’s test expectations and test performance could not be established in this research. In addition, novices in a domain do not have a good impression of what there is to know about a particular problem. Therefore, they cannot determine which information might help them to complete the task at hand. The decisions made by learners on what information to use can result in misconceptions especially when dealing with more complex problems or tasks (Hannafin et al., 1999).

Kester and colleagues (Kester, Kirschner, & van Merriënboer 2004; Kester, Kirschner, & van Merriënboer, in press a; Kester, Kirschner, & van Merriënboer, in press b) tried to overcome these problems by defining the two information types (i.e., supportive and procedural information) beforehand and making them available piece by piece during problem solving. Within the boundaries of this pre-selected information learners could determine themselves what they need at that time. A potential pitfall of this solution is that the system-regulated, piece by piece presentation of information not always fits the information needs of a particular learner. The information that is available at a specific time during problem solving might not be the information that is needed by the learner at that time and might, therefore, interfere with learning and thus, complex skill or competency development. This research proposal, therefore, aims at facilitating competency development not by setting limitations on the available information resources but by providing support to help learners self-regulate their information need.

Learners should be scaffolded in determining their information needs not only with regard to correctly perceiving the task demands (demand-perception scaffolding) but also with regard to grasping the potentially relevant conceptual information (conceptual scaffolding). Besides providing support, scaffolding aims at optimally utilize learners' cognitive capacity during learning. In other words, scaffolding aims at the proper management of the cognitive load imposed on the learner during learning.
The cognitive load that a learner experiences during learning and practice is caused by a combination of the complexity of the problem which is high, especially when using authentic learning tasks, and the design of the instructional materials. The complexity of the problem itself yields intrinsic cognitive load. The design of the instructional material yields either extraneous cognitive load or germane cognitive load. Extraneous cognitive load is caused by the processes that a learner engages in which are not directly beneficial to learning (e.g., searching for relevant information sources, combining different information sources in order to understand the learning material, or weak-method problem solving). Extraneous cognitive load uses up cognitive resources at a cost to learning processes. Germane cognitive load includes all cognitive load associated with processes that a learner engages in that are beneficial for learning (e.g., attending to important features of the problem, or abstracting from a variety of practice problems so as to construct more general cognitive schemata; Sweller, van Merriënboer, & Paas, 1998). With a given intrinsic cognitive load, well-designed learning material minimizes extraneous cognitive load and optimizes germane cognitive load within the thresholds of totally available cognitive capacity.

To minimize the extraneous cognitive load learner support should diminish as expertise increases, that is, scaffolding. Using scaffolding in instructional material prevents the occurrence of the expertise reversal effect (Kalyuga, Ayres, & Chandler, 2003). This effect arises when support, necessary for novice learners in the domain, is also given to more experienced learners who do not need this support any more (Kalyuga, Chandler, & Sweller, 2000). For the more experienced learners the support has become redundant and presenting redundant information during practice hampers learning (Sweller, van Merriënboer, & Paas, 1998).

The germane load can be optimized using scaffolding to help learners correctly perceive the task demands (i.e., demand perception scaffolding) and to grasp the potentially relevant conceptual information (i.e., conceptual scaffolding).

In order to solve a problem (or carry out a learning task) learners have to correctly perceive the following task demands (Newel & Simon, 1972):

- the given state of the problem,
- the criteria for an acceptable goal state, and
- the solution, that is, a sequence of steps that enable the transition from given state to goal state.

Recent research indicates that scaffolding learners during task practice with worked-out examples has beneficial effects on learning and transfer (for an overview, see Atkinson, Derry, Renkl, & Wortham, 2000). Worked-out examples provide learners with an overview of the given state, the goal state, and the solution of a problem or learning task. So, by studying these examples the learners are enabled to form a clear impression of the task demands. In this study worked-out examples will be used to ‘demand-perceptually’ scaffold learners in determining their information need. It is assumed that using the worked examples optimizes germane cognitive load by redirecting learner’s attention to elements relevant for learning namely the sequence of steps that enable the transition from given state to goal state. This should lead to better learning outcomes.

Hannafin et al. (1999) propose several conceptual scaffolding to give the learner an impression of what information can be considered varying from recommendation to use certain tools during problem solving to providing structure maps or content trees. These latter conceptual scaffolding are also referred to as graphic organizers (i.e., figural organizations of text information, Robinson & Kiewra, 1995; Robinson, 1998). Graphic organizers can take many forms (e.g., matrices or tree diagrams) but an important aspect they all have in common is that hierarchical and coordinate relations are depicted in them (Robinson & Kiewra, 1995; Robinson, Katayama, Dubois, & Devaney, 1998).
Several meta studies show inconsistent results with regard to the beneficial effects on learning of graphic organizers (e.g., Robinson, 1998; Griffin & Tulbert, 1995; Rice, 1994; Dunston, 1992; Moore & Readance, 1984). According to Dunston (1992) this is due to variation in the type of organizer used, the timing of organizer presentation, the designers who develop the organizer, and the students who use the organizer. Another important aspect is the way in which a graphic organizer is applied. Chang, Sung and Cheng (2002), for example, studied three variations of applying a concept-map (i.e., a type of graphic organizer) namely map correction (i.e., an expert-generated concept map that contained incorrect concepts and semantic links had to be corrected), scaffold fading (i.e., a completion strategy was used that first provided an expert-generated concept map then a partial expert-generated concept map that had to be completed by the students and ended with a student-generated concept map) and map generation (i.e., students had to generate the concept map from the start). Only one of these variations namely map correction led to better text comprehension while both map correction and scaffold fading led to better summarization ability. This study illustrates that different application of a specific graphic organizer leads to different learning outcomes.

In the present study, graphic organizers will be used to conceptually scaffold learners in determining their information need. It is assumed that this measure also optimizes germane cognitive load by redirecting learner's attention to elements relevant for learning namely important concepts in the learning domain. This should lead to better learning outcomes.

Since, graphic organizers form a very heterogeneous whole it is important to carefully choose one that is most suitable for the situation at hand. Therefore, a literature review will be carried out to decide (1) which type of graphic organizer will be used for conceptual scaffolding, (2) when the organizer is presented and (3) how this organizer will be applied.

Aim of the proposed research project is to find out: (1) if demand-perception scaffolding helps learners to determine their information need, (2) if conceptual scaffolding helps learners to determine their information need, and (3) if redirecting the learner's attention by using demand-perception scaffolding and/or conceptual scaffolding leads to higher learning outcomes. To see whether learners are capable of determining their information need a log tool will be used to monitor the students interactions with the available textual resources. The learning outcomes will be measured by performance scores on the test learning tasks (i.e., learning tasks in which no support or information is provided). It is hypothesized that demand-perception scaffolding and conceptual scaffolding both help learners to determine their information need. Learners provided with demand-perception scaffolding or conceptual scaffolding will use more textual resources than learners who are not provided with scaffolding and learners who receive both types of scaffolding will use most textual resources. Moreover, it is hypothesized that demand-perception scaffolding and conceptual scaffolding both help learners to achieve higher learning outcomes. Learners provided with demand-perception scaffolding or conceptual scaffolding will reach higher test performance scores than learners who are not provided with scaffolding and learners who receive both types of scaffolding will reach highest performance scores.

Importance for the Open University of the Netherlands and the place of the research in the OTEC Research Program, as well as the relation with other OTEC programs

Scientific importance
This research project will shed some light on the issue of information presentation and the acquisition of (complex) cognitive skills. The idea is that just-in-time information presentation could facilitate the process of cognitive skill acquisition but recent research in this area led to some inconclusive results (Kester, Kirschner & van
The approach to just-in-time information presentation in previous research was predominantly task-based: the information was explicitly presented when necessary to perform the task. In this research proposal a learner-based approach to information ‘presentation’ is used: the information is used and retrieved by the learner when needed. This will lead to more insight in just-in-time information presentation and contribute to theory development around this topic.

Importance for the OUNL

Since the OUNL is under financial pressure, more and more of its courses have to be produced with less money maintaining the good quality. A learner-based approach to just-in-time information is expected to be more cost-effective than a task-based approach, and may thus reduce the development costs of distance learning environments. This makes research regarding the innovation and perfection of such environments particularly important for the OUNL.

OTEC research program

This research project is complementary to the PhD-project ‘Just-in-time information presentation and the acquisition of complex cognitive skills’ that was completed on September, 5, 2003.

Relation with other OUNL/OTEC programs

In general this research contributes to knowledge around adaptive learning environments, learner-controlled environments and self regulated learning. Issues that also play a role in the development program. Moreover, this research aims at enrichment of already used didactical methods and can lead to insights that are relevant for the implementation program.

c Design & Methods

Participants

Students of the Open University of the Netherlands will participate in this study.

Material

Domain/course

An appropriate learning task will be selected from a suitable course of the open university which will be adjusted to meet the experimental requirements. These requirements are:

- sufficient complexity (i.e., the learning task has to be in the zone of proximal development of the participants),
- sufficient length (i.e., the participants need a certain amount of time to elaborate the relevant information),
- sufficient resources (i.e., enough information has to be available for the participants),
- adjustment possibilities (i.e., the learning material should allow for experimental adjustments).

Scaffolding

A 2x2 factorial design with the factors demand-perception scaffolding (added or not added) and conceptual scaffolding (added or not added) is used to test the assumptions. This results in four task formats, one in which both scaffolding methods are used, one in which no scaffolding methods are used, one in which only demand-perception scaffolding is used and one in which only conceptual scaffolding is used.

Practice tasks and Test tasks

A series of learning tasks will be administered to the participants in which the demand-perception support and the conceptual support is gradually faded. This is accomplished by providing less and less detailed worked-out examples or graphic organizers. The last tasks are not accompanied by support or relevant information at all and will serve as test tasks (see Figure 1).
Figure 1: Schematic overview of the sequence of learning tasks (LT) that are administered during the experiment. Note that the exact amount of learning tasks that will be presented is not yet established.

Log tool
A logging program will be used in the experiment. This program keeps track of the time on task and the navigation of the participants through the learning tasks. This program generates a text file with a list of window headers coupled to a timestamp, so, the route the participants follow through the learning material and the time it takes them to complete it can be determined.

Mental effort measurement
Mental effort will be used as an index of cognitive load. It refers to the amount of cognitive capacity allocated to problem solving. Mental effort will be measured during both practice and the test with a 9-point rating-scale (Paas, 1992; Paas, Van Merriënboer, & Adam, 1994). The mental effort measures range from very, very low mental effort to very, very high mental effort. The rating-scale will be administered during practice and during the test directly after each learning task.

d Literature


### 13 Work program and planning

<table>
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<th>Activity</th>
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<td>2004</td>
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<tr>
<td>June</td>
<td>Literature study</td>
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<td>July</td>
<td>Literature study + problem/task design</td>
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<td>August</td>
<td>Literature study + problem/task design + writing article 1</td>
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<tr>
<td>September</td>
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<td>October</td>
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<td>November</td>
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<td>2005</td>
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<td>Month</td>
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<td>February</td>
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<tr>
<td>March</td>
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