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Abstract

This study focuses on the development of a complex web-based learning environment aimed at promoting the acquisition of applicable knowledge in the context of studying empirical research methods at university. This learning environment was then modified further on an empirical basis. The main focus of the present article is to describe the conceptualisation of the learning environment and research activities which were guided by an integrative research paradigm. The learning environment consisted of highly structured, complex texts in which the process of empirical research was illustrated in a detailed manner. By combining these texts with other instructional measures, the learning environment is given a flexible hypertext-structure. The effectiveness of the learning environment as a whole was investigated in three studies (two evaluation studies in the field and one experimental study in the laboratory). It was demonstrated that the additional instructional measures (e.g. a specific feedback-guidance and time-management measures) were not effective. The importance of cognitive, motivational and emotional learning prerequisites for the successful utilisation of the learning environment was highlighted. The implementation of special training and additional preparatory modules is recommended in order to optimise the fit between students' prerequisites and learning environment.

Keywords: applicable knowledge, empirical research methods, instructional measures, integrative research paradigm, learning behaviour, web-based learning environment

Zusammenfassung

Im Zentrum der vorliegenden Arbeit steht zum einen die Konzeptualisierung einer Lernumgebung zur Förderung des Erwerbs anwendbaren Wissens im Kontext der universitären Ausbildung in empirischen Forschungsmethoden. Zum anderen werden ausgehend von einem integrativen Forschungsparadigma Forschungsaktivitäten beschrieben, die die empirische Basis zur Weiterentwicklung der Lernumgebung bereitstellen. Die Lernumgebung besteht aus hoch strukturierten, komplexen Texten, in welchen der Prozess empirischer Forschung auf detaillierte Weise veranschaulicht wird. Diese Texte wurden mit anderen instruktionalen Maßnahmen kombiniert, wodurch die Lernumgebung eine flexible, hypertextartige Struktur bekam. Die Effektivität der gesamten Lernumgebung wurde im Rahmen dreier empirischer Studien untersucht, von denen zwei als Evaluationsstudien im Feld durchgeführt wurden; die dritte war eine experimentelle Laborstudie. Es wurde gezeigt, dass die zusätzlichen instruktionalen Maßnahmen (z. B. eine spezifische Feedback-Anleitung und eine Zeitmanagement-Maßnahme) nicht wirksam waren. Die Bedeutung kognitiver, motivationaler und emotionaler Lernvoraussetzungen für die erfolgreiche Nutzung der Lernumgebung konnte nachgewiesen werden. Um die Passung zwischen den Eingangsvoraussetzungen der Studierenden und der Lernumgebung zu verbessern, wurde die Implementation eines speziellen Trainings und eines zusätzlichen vorbereitenden Moduls vorgeschlagen.

Schlüsselwörter: anwendbares Wissen, empirische Forschungsmethoden, instruktionale Maßnahmen, integratives Forschungsparadigma, Lernverhalten, netzbasierte Lernumgebung.

WEB-BASED LEARNING IN THE FIELD OF EMPIRICAL RESEARCH METHODS

Lack of applicable knowledge in the field of empirical research methods

In several disciplines of the social sciences, empirical research methods and statistics form an important part of the curriculum. For many students, however, this subject poses serious difficulties. The failure rates in the methods courses are high, the motivation of the students to learn and their interest in working with research problems is often low. Students are also often anxious about the subject matter. Consequently, at the end of the courses the knowledge base of the students is often deficient: extensive knowledge gaps and misconceptions are apparent (Stark & Mandl, 2000a). Later on, in their professional life, many students are not competent in applying empirical research methods. In a study of Oakes (1986) which was replicated at a German university (Haller & Krauss, 2002), clear misconceptions and knowledge gaps concerning the concept of statistical significance were identified. This was not only true of students, but also of researchers and university lecturers all of whom had difficulties interpreting the results of a simple *t*-test.

However, these insights are nothing new. To date, many experts of the field have complained repeatedly about the flawed application of core statistical concepts and procedures in the field of quantitatively oriented empirical research (e.g. Cobb, 1993; Cohen, 1990; 1992; 1994; Dar, Serlin & Omer, 1994; Gigerenzer, 2000; Sedlmeier & Gigerenzer, 1989; Stelzl, 1982; Wottawa, 1990).

Stark and Mandl (2000a) proposed a multi-dimensional model to explain these problems; negative cognitive, motivational and emotional learning prerequisites and unfavourable attitudes concerning empirical research methods influence each other and lead to ineffective learning behaviour. The situation is often exacerbated by an unfavourable instructional setting. As a rule, mandatory courses are attended by a very large number of students while the number of university teachers and peer tutors is not sufficient.

Intervention strategy

After detailed analyses of these problems, the courses in empirical research methods for students of educational psychology at Munich university were comprehensively reformed (Stark & Mandl, 2000a). Firstly, a distinctly *application-oriented* curriculum was developed. In addition, *problem-oriented* lectures and exams were introduced in which the main principles of situated learning were combined with more traditional instruction (Reinmann-Rothmeier & Mandl, 2001). The problem-oriented concept of the courses included an explicit *motivational perspective* (Stark & Mandl, 2000a). In order to compensate for inadequate teacher and tutor capacity, a complex web-based, virtual learning environment called *NetBite* was developed and implemented.

The main goal of this article is to describe the theoretical concepts and the step-by-step evaluation of the learning environment. Both the conceptualisation and the evaluation concentrate on the part of the learning environment which is employed in the second half of the standard courses in empirical research methods at Munich university (in the following called *NetBite 2*). Building on the main results of an initial evaluation study in the field, a second field study was carried out, which will be described in detail. This study formed the basis of an experimental study in the laboratory which also will be reported in detail. Before these studies are described, the conceptualisation of applicable knowledge will be presented; then, theoretical considerations are provided concerning the selection of the learning method to be implemented and the comprehensive research strategy by which the empirical studies were guided.

Application of knowledge in the context of the reformed courses on empirical research methods

At the end of their coursework in empirical research methods, students should understand central concepts and principles of descriptive and inference statistics and be able to apply them successfully on typical research questions. In order to achieve this goal, serious misconceptions (for example misconceptions concerning the concept of statistical significance) have to be overcome. Students should be able to formulate research questions and hypotheses from research problems and typical problems of practice and be able to develop simple research designs. Moreover, they should be able to select and apply statistical procedures mindfully by using special statistics software and be able to interpret their results adequately. This knowledge base, which includes both differentiated declarative and procedural components, should enable the students to understand and critically analyse scientific literature in their discipline, especially with respect to the research methods employed there and the relation between theory and research methods. At least to some extent, the students should develop competence in some relevant aspects of *scientific thinking* in the context of their discipline.

Previous considerations regarding the learning method and the additional instructional measures to be implemented

There are good reasons to suppose that knowledge acquisition in the field of empirical research methods can be fostered efficiently by utilising principles of *example-based learning*. In various domains, learning environments based on worked-out examples proved to be highly effective and efficient (mathematics: Cooper & Sweller, 1987; computer programming: Paas & Van Merrienboër, 1994). This seems to be particularly true when fostering the initial acquisition of cognitive skills in well-structured domains, such as empirical research methods (VanLehn, 1996).

However, example-based learning is not effective per se. Renkl (1997) showed that the majority of learners tends to work with sample solutions in a rather superficial and passive way; as a result, they profit much less from this learning method than they probably could. At least to a certain degree, ineffective learning behaviour can be caused by comprehension problems and/or deficient prior knowledge – problems which the learners cannot overcome without additional instructional support.

In order to compensate for these problems, *instructional explanations* (Renkl, 2002) should be integrated in the learning environment. In order to support self-directed learning, these explanations should be adaptive and optional (Renkl, 2001).

In addition, in order to motivate learners and to foster the quality of information processing, *incomplete solution steps* should be utilised (Van Merrienboër & Paas, 1990). In the domain of probability calculation, the quality of the learning behaviour as well as learning outcomes were fostered significantly by this instructional measure (Stark, 1999). In order to give the learners the chance to diagnose their errors in understanding and knowledge gaps, *immediate feedback* must be provided, for instance by providing correct model solutions.

However, even when immediate feedback is used in the form of *knowledge of correct response* according to Kulhavy, White, Topp, Chan, and Adams (1985), it does not ensure intense and systematic processing of the feedback. Students often show deficiencies in this aspect of meta-cognitive control of their own learning progress. In order to compensate for these shortcomings, specific feedback guidance must be provided as well. This measure should encourage learners to compare their self-generated solutions systematically with model solutions, for example by providing specific questions.

In the field under consideration, the design of the learning environment should also be guided from a *motivational perspective*. In order to promote the motivating effects of the learning environment, *situated design principles* can be very useful, for example according to design recommendations of the Cognition and Technology Group at Vanderbilt (e.g. CTGV, 1997). Some of these principles were applied successfully to the design of an earlier version of the learning environment (Stark & Mandl, 2000b).

Concrete realisation of the learning environment

The web-based learning environment *NetBite 2* is based on two extensive *basic texts*. The first one starts with an *authentic* and *relevant* research problem: The students have to assume the role of an expert who has to evaluate a computer-based learning environment conceptualised to foster understanding of Darwinian concepts at a high-school level. Using this as a starting point, the process of empirical research is visualised in a step-by-step manner. That is, the application of central concepts, principles and procedures of empirical research is demonstrated in the context of a concrete application-oriented research problem (*narrative format*; CTGV, 1997). This design principle is realised in the second basic text in an analogous way.

The two basic texts are supplemented by two types of *instructional explanations* in such a way that the learners are free to make use of them whenever they choose (e.g. Renkl, 2001). By clicking on explanations of type 1, short definitions and taxonomies appear; explanations of type 2 provide further information about application contexts, relations to other concepts and procedures as well as advantages and disadvantages of concrete decisions and proceedings at hand. As short and elaborated explanations are connected with each other, the learning environment is given a hypertext-like structure.

Additionally, selected solution steps in both basic texts are presented in an *incomplete* way. In order to support the intensity and quality of feedback processing, a specific *question-rationale* is also implemented. These questions encourage learners to analyse similarities and differences between their self-generated solutions and the model solutions provided automatically by the learning environment.

In summary, *NetBite 2* consists of two basic texts demonstrating central steps of empirical research. In these texts, both short and elaborated explanations are integrated. In addition, incomplete solution steps and specific feedback guidance is provided. Selected areas of the learning environment can be visited on the internet (*www.netbite.emp.paed.uni-muenchen.de*).

Application of an integrative research paradigm

In order to optimise and evaluate the learning environment, three empirical studies were carried out so far (two evaluation studies in the field and one experimental study in the laboratory). The conceptualisation of these studies was guided by the *integrative research paradigm* (Mandl & Stark, 2001; Stark, 2001). An important goal of this research paradigm was to generate scientific knowledge with an explicit application-oriented perspective in order to bridge the gap between theory and practice. Controlled *design experiments* (Brown, 1992) in the field were systematically combined with experimental studies in the laboratory. In these studies, the partial incompatibility of internal and external validity was dealt with by carrying out *controlled* field studies with experimental and quasi-experimental components on the one hand and use-inspired experiments with a clear practical orientation on the other (Stark, 2001).

In order to increase the output of this methodological strategy, both quantitative and qualitative procedures were employed (Mayring, 1999; Renkl, 1999). In addition, a strong *motivational perspective* was included in the evaluation. In the context under consideration, it is especially important to focus on motivational aspects such as the interest and intrinsic motivation and self-concept of the learners (Stark & Mandl, 2000a). In addition, the anxiety of the learners with respect to the mathematical subject matter has to be taken into consideration.

Together with cognitive learning prerequisites, especially domain-specific prior knowledge and experience to learn with computers, these variables have to be controlled in order to secure the internal validity of the studies. Furthermore, they have to be studied as potential *moderating variables* (Hartley & Bendixen, 2001). However, a differentiated diagnostic of motivation also has to take into consideration motivational processes *during* the learning sessions (for example the learners self-efficacy) and motivational *consequences* (e.g. Stark, 1999). Especially with regard to the effective long term-implementation of the learning environment, aspects like the learners' evaluation of their own learning progress and their acceptance of the learning environment are central aspects which probably influence their endurance and willingness to further invest cognitive effort.

This research paradigm was applied in three empirical studies. The main results of the initial evaluation study which built the basis for the subsequent studies are summarised in the following section.

Empirical studies to optimise and evaluate the web-based learning environment

Goals of the initial evaluation study

The main goal of the initial evaluation study (Stark & Mandl, 2002) was to compare mean effects of the learning environment on learning outcomes with the effects of a control condition. In addition, the effectiveness of the *feedback guidance* described above was investigated. Two versions of the learning environment were implemented under regular learning conditions in the field; these versions only differed with respect to the feedback guidance. As this guidance confronts the learners with an additional comparison task, cognitive load (Sweller, Van Merrienboër, & Paas, 1998) and time-on-task might be increased. However, if the quality of feedback processing and learning outcomes can be increased substantially, these consequences can be tolerated.

Main results

NetBite 2 proved effective. Students who worked with the learning environment acquired significantly more applicable knowledge than students who only visited the regular lectures but had no access to *NetBite 2*; the size of the effect was medium.

Concerning domain-specific prior knowledge, students in the control group and the two experimental groups were comparable.

However, the feedback guidance had no effect on knowledge acquisition. Cognitive, motivational and emotional learning prerequisites did not differ significantly in the experimental groups. In addition, learning outcomes were not influenced by these variables.

The feedback guidance did not influence cognitive load. However, at the beginning of the learning phase, cognitive load scores were already high in *both* experimental conditions and even increased throughout the course of the learning phase.

Time-on-task was increased significantly by the feedback guidance. However, time-on-task data which was registered for various components of the learning environment made it apparent that the potential of *NetBite 2* was by far not used exhaustively by the learners: Several students began studying the learning environment rather late, no more than a few days before the regular exam. That is, despite the opportunity to distribute their learning sessions over a six-week period, the students primarily used the learning environment as a short-term learning tool. In addition, the learning behaviour of the majority of the students was very superficial: The feedback guidance questions were often answered only superficially or not at all. This also held true for the students' interaction with the incomplete solution steps and both types of instructional explanations which were often not used at all.

Discussion

Firstly, it must be reiterated that the students profited from learning with *NetBite 2* in spite of their sub-optimal learning behaviour. However, it is possible to assume that they would profit even more if these problems could be overcome at least to some extent, for instance through improvements in the learning environment concerning the structure of the provided material.

The sub-optimal learning behaviour of the students clearly indicated by their problematic time-management can be attributed to deficiencies in *self-directed learning* (Friedrich & Mandl, 1997). Such deficiencies lead to serious shortcomings, especially when complex web-based learning environments are implemented (e.g. Hartley & Bendixen, 2001). *NetBite 2* allows students of educational psychology who are at the beginning of their studies more "degrees of freedom" than they are accustomed to from traditional instruction at school. As a matter of fact, even at the university level the learning prerequisites which enable students to cope competently with such a learning environment cannot be expected.

This interpretation of the unexpected findings were supported by *qualitative* data (Stark, 2001). Students complained about orientation problems, problems of organising their learning process and especially about problems of evaluating their learning progress validly and drawing conclusions for their further learning behaviour. It can be assumed that these problems not only reduced the learners' knowledge acquisition but also their acceptance of the learning environment.

Modifications to the learning environment

On the basis of these findings, the learning environment was modified substantially. For instance, technical aspects were improved, the basic texts were shortened and the incomplete solution steps were reduced and simplified. The main modification, however, was directed at facilitating the students' time-management by pre-structuring the basic texts of the learning environment. The effects of this time-management measure was investigated in the second evaluation study which is described in more detail below.

Evaluation study 2

Goals of the second evaluation study

The main goal of the second field study was to evaluate the influence of time-management measures on learning outcomes, cognitive load and motivational aspects. Another central research question considered the learning behaviour of the students. However, before the main results of this study are reported, some theoretical considerations are necessary.

Supporting time-management through a "new" instructional measure

The problem-oriented "philosophy" of the reformed courses in empirical research methods at Munich university (Stark & Mandl, 2000a) explicitly focuses on situated and therefore *self-directed* aspects of learning. However, it also places emphasis on the necessity of *instructional support* (Reinmann-Rothmeier & Mandl, 2001) in order to enable learners to really benefit from dealing with complex problems in their field. As a consequence, the majority of learners should not be overtaxed by the learning environment. In order to compensate for the self-regulation deficiencies of the students which led to their sub-optimal learning behaviour in the initial field study, additional support is required. The students must be supported to structure their learning sessions both in content- and time-related aspects. In order to determine the degree of instructional pre-standardisation the students profit mostly from when working with *NetBite 2*, three versions of the learning environment were conceptualised: a completely pre-structured version, a more adaptive version in which only recommendations for self-structuring the learning sessions were provided and a completely "open", non-structured version.

In the completely *pre-structured version*, the basic texts of the learning environment was presented each week in short content-specific sections; the students who were assigned to this version (*n*=34) only had access to these selected sections.

Students in the *adaptive condition* (*n*=30) only were given the recommendation to work in weekly sections; that is, they were free to structure their learning sessions on their own. Thus, the adaptive version represents a compromise between self-regulation and directivity. This might be especially effective for students who behave in a reactive manner (Dickenberger, Gniech & Grabitz, 1993) when asked to work on the texts of the learning environment in the weekly "bit-by-bit" manner.

However, it is clear that compared to the completely pre-structured version, the increased "degrees of freedom" of the adaptive version places higher demands on the self-regulative competence of the learners.

Students assigned to the *non-structured version* (*n*=24) received no support concerning time-management.

It was supposed that both the pre-structured and the adaptive version of the learning environment reduce cognitive load and have positive effects on knowledge acquisition.

Analysis of motivational effects

In the initial evaluation study, motivational effects were not recorded systematically; they were only deduced from qualitative data. In the second evaluation study, the focus shifted to the acceptance of various components of the learning environment and the learners' evaluation of their own learning success. Especially in a long-term learning context, these related aspects are very important to encourage the learners' level of persistence (Stark, 2001). Therefore it is important to find out what influence the time-management measures had on these aspects.

Analysing different aspects of learning behaviour

In order to gain more information about the learning process, different procedures were employed. Time-on-task data were registered in a similar fashion as in the initial study. In addition, the learning behaviour of the students was analysed by a special rating scale on which they had to comment on the way they used *NetBite 2*. This rating scale was based on theoretical considerations and empirical evidence about different ways of dealing with the provided solution steps (e.g. "I tried hard to really understand the solution steps"; "I only skimmed the pages").

Furthermore, the learner-generated completions of the incomplete solution steps were analysed systematically. They were compared with sample model solutions concerning a) correctness and b) completeness. Domain-specific propositions were used as unit of analysis.

Additionally, the students had to answer a special rating scale by which they had to make transparent how they used different resources "outside" the learning environment to prepare for the regular exams in empirical research methods. In order to secure internal validity of the study, a control group of students who had no access to *NetBite 2* also was given this rating scale.

Main results

Knowledge acquisition, cognitive load and learning prerequisites

NetBite 2 was effective in the second evaluation study as well. Students working with *NetBite 2* acquired significantly more applicable knowledge than students who visited the regular lectures but had no access to the web-based learning environment. The effect-size of the differences was medium. Concerning domain-specific prior knowledge, students of the control group were comparable to students of the three experimental groups.

Contrary to our expectations, however, the time-management measures were not effective: Neither the completely pre-structured nor the adaptive version fostered knowledge acquisition! Concerning cognitive and motivational prerequisites, students in the three experimental conditions were comparable. Learning outcomes also were not related to these learning prerequisites.

Compared to the non-structured version, both the completely pre-structured and the adaptive versions, which were supposed to reduce cognitive load, actually *increased* cognitive load significantly. The effect strengths of the differences were medium.

Time-on-task

On average, the students worked 10 hours with *NetBite 2*. Students in the three experimental groups did not differ significantly in time-on-task. Deeper analyses of time-related data made it apparent that a lot of learners in the pre-structured condition worked on their weekly sections primarily at the beginning and the last day before the next section was provided. In the adaptive condition, only half of the students followed the recommended time line; however, even these students showed the tendency to work on the recommended section only shortly before the next section had to be studied. Students who received no pre-structuring predominantly concentrated their efforts at the end of the provided time span. That is, they showed time-management tendencies which were already known from the initial study.

Learning behaviour

Concerning the exam-related preparation behaviour "outside" the learning environment, students in the control group did not differ significantly from students in the experimental groups. Learners in the three experimental groups were also comparable with respect to their learning behaviour. Their self-rated ways of coping with the learning environment also differed only marginally.

This also holds true for the correctness and the completeness of the learner-generated completions. In summary, the time-management measures did not influence these aspects of the learning behaviour.

Acceptance and self-evaluated learning success

The mean acceptance of various components of the learning environment was high and nearly reached the theoretical maximum of the acceptance scale. The means of the students' evaluation of their own learning success were also high. The time-management measures did not influence the acceptance aspects or the subjective learning outcomes.

Discussion

Similar to the initial evaluation study, *NetBite 2* clearly fostered the acquisition of applicable knowledge. However, at least on a more abstract level, another important but unexpected result of the initial study was replicated as well. The learning environment was not made more effective by using an additional supporting measure. Neither the weekly pre-structuring of the provided texts nor the more adaptive version, which only recommended working on weekly sections proved to be effective. Contrary to our expectations, these time-management measures did not even reduce cognitive load. Moreover, they did not influenced the students' learning behaviour or motivation.

Analyses of time-on-task data made it apparent that the problematic time-management which was diagnosed in the initial evaluation study in general was not significantly altered by the additional time-management measures. The students at best showed *superficial commitment* and managed to avoid an intense weekly session using the pre-structured sections. As a matter of fact, a lot of students kept to their sub-optimal short-term learning mode which seemed to be predominantly influenced by the impending approach of the regular exam.

Interestingly, the self-evaluation data concerning different aspects of the students' learning behaviour did not correspond at all to "objective" time-related indicators: According to the self-evaluation of the students, they worked on the texts fairly regularly and intensely. The acceptance data and the data on subjective learning success also did not indicate any problems. On the contrary, the students seemed to be highly content with the learning environment and their learning success. However, the "objective" learning outcomes at least to some extent did not support this rather optimistic self-evaluation.

Social desirability effects could be held at least partially responsible for the lack of correspondence between subjective and "objective" data. In addition, it is important to bear in mind that the perspective of teachers/researchers can and often *does* differ greatly from the perspective of students: Students may apply completely different standards when they describe their learning behaviour and evaluate their progress. Lastly, but most importantly in the present context, the students' deficiencies in self-directed learning diagnosed in the initial field study seem to be deeply rooted in *meta-cognitive* deficiencies (Stark & Mandl, 2002). These deficiencies by definition interfere with valid self-descriptions concerning multiple aspects of the learning process.

These kinds of deficiencies could also explain why the instructional explanations, which from an educational perspective should have proved helpful, were frequently ignored by the students. Sub-optimal help seeking-behaviour was also observed in several studies in which other kinds of learning environments were investigated (Aleven, Stahl, Schworm, Fischer, & Wallace, 2002; Hofer, Niegemann, Eckert, & Rinn, 1996); this seems to be a general problem when supporting complex learning.

Consequences of further modifications to the learning environment

Due to these at least partly disappointing findings, the learning environment was widely modified once more. At first, the usability of *NetBite 2* was improved, for example by optimising the appearance of the presented pages. Some of the instructional explanations were shortened and structured more clearly. Additionally, the instructions concerning the use of instructional explanations was altered. In the new instructions, emphasis was placed on the functionality of the instructional support with respect to understanding and supporting problem-solving processes. In addition, some hints concerning selective use of instructional explanations were provided.

The most important "innovation", however, concerned the implementation of a "new" instructional measure: comprehension questions. This measure was primarily aimed at fostering the learners' ability to competently evaluate their learning progress and comprehension problems. However, according to the integrative research paradigm, the effects of this instructional measure were not investigated in the field but under controlled conditions in the laboratory (see Stark & Mandl, in press).

Experimental study in the laboratory

Goals of the laboratory study

The main goal of the laboratory study was to systematically investigate the influence of specific comprehension questions on learning outcomes, cognitive load, time-on task and motivational aspects. In addition, effects of another measure, which was already implemented in the last two evaluation studies, were to be investigated under experimental conditions: incomplete solution steps.

In this study, the motivational perspective was realised in a more differentiated way than in the field studies: Not only the motivational prerequisites and consequences were analysed, but also the motivational aspects *during* the learning session (self-efficacy and intrinsic motivation).

Moreover, an additional "new" research perspective was introduced: The relevance of various learner prerequisites in the context of using the web-based learning environment was analysed cluster-analytically in order to identify different types of learners.

Because of time-on-task limitations in the laboratory setting, a short version of *NetBite 2* was utilised which focused on the first basic text. However, before the main results are described, some theoretical considerations are discussed.

Formulating comprehension questions

12 comprehension questions were developed; these questions concentrated on domain-specific concepts and statistical procedures, which proved to be difficult for students of educational psychology to comprehend (e.g. "Which conclusions can be drawn from the interaction effect at hand?"). All questions were integrated in the first basic text and presented in a multiple choice format which confronted the learners with four answer alternatives to select from. This presentation format was combined with an automatic presentation of the model solution, which was explained in detail. In this way, *elaborated feedback* (Jacobs, 2001) was given immediately.

This instructional measure should compensate meta-cognitive deficiencies by giving the learners the chance to control their standard of knowledge adequately and by evaluating their learning progress in an efficient way. Therefore, positive effects on learning outcomes were expected.

The second instructional measure (presentation of incomplete solution steps) was also varied experimentally. This measure had already been implemented in the both evaluation studies described above, but it was not varied experimentally in these studies. Varying both instructional measures (comprehension questions and the incomplete solution steps), a 2×2-factorial design with four learning conditions resulted. 15 students of educational psychology were assigned randomly to each condition.

Analysis of learning prerequisites

In the two evaluation studies described above, learning prerequisites were primarily recorded to secure internal validity and to identify aptitude-treatment-interactions (Cronbach & Snow, 1977) which could have consequences for optimising the learning environment. Basing on theoretical considerations, the learning prerequisites considered so far (domain-specific prior knowledge, intrinsic motivation, domain-specific self-concept and anxiety) were complemented by additional aspects which in the given context could be relevant as well: studying experience (indicated by the students' semester), experience to learn with computers, and attitudes towards empirical research methods (Stark & Mandl, in press). However, the influence of these aspects was not only analysed in the usual isolated manner. In the laboratory study, an additional research perspective was introduced. In the first step, homogenous sub-groups of learners were identified on the basis of these learning prerequisites. In the second step, these learner-profiles were related to learning outcomes and motivational aspects.

Main results

Learning outcomes and learning prerequisites

Firstly, it must be stated that on average the students of educational psychology who participated in the experimental study benefited from working on the short version of the learning environment. Learning progress was significant and practically relevant.

Contrary to our expectations, acquisition of applicable knowledge was not fostered by comprehension questions or by providing incomplete solution steps. As the four experimental groups did not differ significantly with respect to cognitive, motivational and emotional learning prerequisites and attitudes towards empirical research methods, the internal validity of the study was given.

However, a strong effect of prior knowledge and also a clear motivation effect was shown: Students with a higher level in prior knowledge and students with higher intrinsic motivation profited more from using the learning environment. These effects were independent from the instructional measures. In addition, there were moderate interaction effects with respect to domain-specific self-concept and anxiety. These two learning prerequisites were moderated by the instructional measures. Especially when incomplete solution steps were provided in combination with comprehension questions, students with a favourable self-concept and low anxiety profited from learning with the short version of *NetBite 2.*

Cognitive load and time-on-task

Concerning cognitive load, the means of the four groups were near the theoretical mean of the scale; semantically, the mean of this scale already indicates some interference with successful learning. No effects of the instructional measures were found.

On average, the students worked two hours with the short version of *NetBite 2*. Time-on-task was increased significantly and substantially by the incomplete solution steps. Interestingly, comprehension questions did not at all increase time-on-task.

Self-evaluated learning success and acceptance

Concerning both variables, the means of all groups were high and not far from the theoretical maximum of the used scales. The two instructional measures did not influence self-evaluated learning success and acceptance.

Self-efficacy and intrinsic motivation during the learning phase

Both the combination of incomplete solution steps and comprehension questions and the provision of complete solution steps without comprehension questions had a positive effect on self-efficacy. Only the interaction between the two experimental factors was significant. Concerning intrinsic motivation, another pattern of results emerged; intrinsic motivation in the learning phase was positively influenced by the comprehension questions. Incomplete solution steps did not influence intrinsic motivation.

Learner profiles

Four learner profiles were identified cluster-analytically (see figure 1). The first profile describes 16 students who are at the beginning of their studies. This profile only slightly differs from the total mean of all profiles with respect to prior knowledge, experience to learn with computers, intrinsic motivation, self-concept, anxiety and negative attitudes towards empirical research methods. Therefore it was named the profile of *average students*.

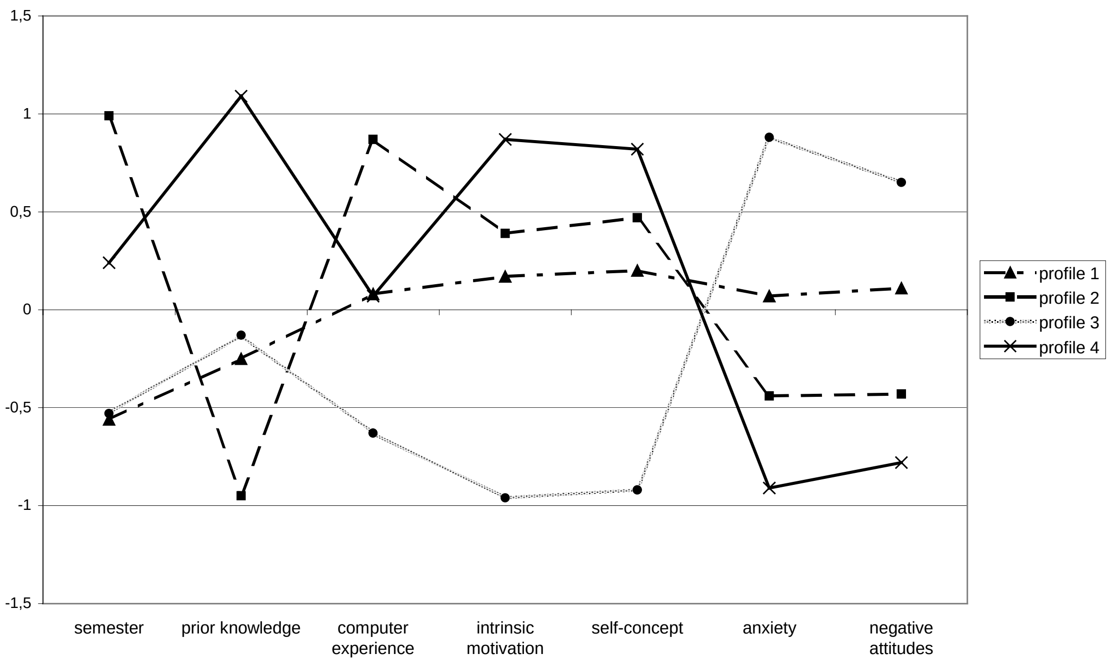

Figure 1: Learner profiles identified on the basis of seven learning prerequisites.

The second profile characterises students with a markedly low prior knowledge-level (profile of students with *deficient prior knowledge*; *n*=9). Concerning study experience, experience to learn with computers, intrinsic motivation and self-concept, this profile lies above the total mean of all four profiles. With respect to anxiety and negative attitudes towards empirical research methods, the second profile lies below the total mean.

The third profile describes students with markedly low intrinsic motivation and self-concept (profile of *unmotivated* students; *n*=9). Concerning prior knowledge, study experience and experience to learn with computers, this profile also lies slightly below the total mean. Anxiety and negative attitudes towards empirical research methods are above the total mean (see figure 1).

The fourth profile characterises 11 students with a high level of prior knowledge. These students have slightly above-average study- and computer-experience and show high scores in intrinsic motivation and self-concept. At the same time, their anxiety and their negative attitudes towards empirical research methods are low. Therefore, this profile was named the profile of *successful* students.

The distribution of the four learner profiles over the four learning conditions was comparable; that is, there was no relation between learner profiles and learning condition.

Learner profiles and relations to learning outcomes and motivational effects

Concerning the acquisition of applicable knowledge, students with different profiles differed significantly. The sub-group of successful students (profile 4) was more successful in the post-test than the three other sub-groups. The sub-group with deficient prior knowledge (profile 2) was least successful. These differences were practically relevant; they were not related to the two instructional measures and also independent from time-on-task.

Concerning self-efficacy and intrinsic motivation during the learning session, sub-groups with different profiles differed as well. The sub-group of successful students (profile 4) showed both the highest self-efficacy and the highest intrinsic motivation during the learning phase; the lowest self-efficacy scores were recorded for the sub-group of unmotivated students (profile 3); the lowest scores in intrinsic motivation were shown in the sub-group of average students (profile 1). These differences also were significant and substantial and not related to the instructional measures.

With respect to self-evaluation of the learning success and acceptance of the learning environment, differences between learners with different profiles were small and not statistically significant.

Discussion

Learning progress and effectiveness of the instructional measures

The short version of *NetBite 2* proved effective and highly efficient. After a short learning session, most students were able to cope with problems which were far too difficult for them *before* they started the learning session. So the evaluation results concerning the effectiveness of the learning environment described above (see also Stark & Mandl, 2002; Stark & Mandl, in press) were replicated under experimental conditions.

However, the effectiveness of the learning environment was independent from the additional instructional measures. Contrary to our expectations, the acquisition of applicable knowledge was not fostered by providing incomplete solution steps or by integrating comprehension questions. The positive effects of incomplete solution steps, which were achieved in former studies (e.g. Stark, 1999) were not replicated. This also holds true for comprehension questions, which were also effective in other studies (e.g. King, 1994; Renkl, 2001; 2002).

In order to explain these counter-intuitive results, three hypotheses were contrasted with the empirical data: a *motivation hypothesis*, a *cognitive load hypothesis* and a *learning behaviour hypothesis*.

Motivation hypothesis

In brief, negative motivational effects cannot be blamed for these unexpected findings. In all learning conditions, learners seemed to be confident with their learning success; the acceptance data can be cautiously interpreted in terms of a highly positive evaluation of the learning environment including the instructional measures. The result pattern which emerges with respect to motivational processes was also favourable. Through comprehension questions, intrinsic motivation during the learning session was clearly increased; incomplete solution steps had at least no negative effects on intrinsic motivation. Moreover, the combination of both measures resulted in high self-efficacy scores. In sum, the motivation hypothesis is not supported by the data.

Cognitive load hypothesis

As the instructional measures did not increase cognitive load, the unexpected results cannot be directly explained by unfavourable cognitive load effects. However, the descriptive cognitive load-data at least *indirectly* point to another plausible hypothesis. Even in the "pure" version, that is, in the version without additional instructional measures, the learning environment proved to be clearly demanding. Therefore it is plausible to assume that students who were confronted with the additional task to complete incomplete solution steps and/or to answer comprehension questions tried to ignore these additional tasks and primarily concentrated on the basic text of the learning environment. Consequently, the students did not really become involved in mindfully interacting with incomplete solution steps and comprehension questions. This plausible cognitive load hypothesis is connected with the following hypothesis focussing on the students' learning behaviour.

Learning behaviour hypothesis

Post-experiment analyses of the learner-generated completions made it apparent that a lot of completions were not complete or left totally blank. Especially the completions of the more complex gaps often were very superficial and flawed. In spite of the increased time-on-task, the quality of most completions make it clear that the learners did not invest much effort in the completion process.

A similar picture emerged when the students' answers to the multiple choice questions were analysed: even the answers to simple questions were often not complete and incorrect. Therefore it is plausible to assume that the students would have profited from a more mindful elaboration of the automatic feedback windows of the learning environment. However, such elaboration processes would have increased time-on-task substantially – but this was not the case. Therefore, not only the answer-behaviour of the students, but also their related feedback elaboration seem to have been superficial and deficient.

In summary, it can be stated that both instructional measures were not given a "chance" to demonstrate their potential because they were largely ignored by the learners. However, neglected in such a way, they at least could not interfere with successful learning by increasing cognitive load. This risk is by no means trivial when complex learning environments are implemented.

Importance of learner prerequisites

The analysis of potential influencing factors was productive: Independent from the instructional measures, a practically relevant prior knowledge-effect and a clear motivation effect were identified. In accordance with several earlier studies (e.g. Dochy, 1992; Schiefele, 1996), learning progress was supported by prior knowledge and intrinsic motivation. It was also influenced by domain-specific self-concept and anxiety; however, the effects of these two learning prerequisites were moderated by the instructional measures. The resulting aptitude-treatment-interactions point to the fact that not all students profited equally from the learning environment. A favourable self-concept and low anxiety proved to be an especially important factor in determining when the learning environment was "enriched" by both instructional measures. The other three learning conditions seemed to be less "discriminating" with respect to these two learning prerequisites.

From an instructional perspective, these findings are problematic in different respects. At first, in the context under consideration, several learners do not meet the necessary requirements for effective learning (Stark & Mandl, 2000a). This would be less problematic if the additional instructional measures compensated for respective learner deficiencies. But this seems not to be the case. On the contrary, incomplete solution steps and comprehension questions, especially when combined, were not only *cognitively* demanding; obviously they also afforded high – probably too high – standards concerning *motivational* and *emotional* dimensions.

Learner profiles and relations to learning outcomes and motivation

On the basis of seven learner characteristics, which were selected on a theoretical and empirical foundation, four learner profiles were identified. The differences observed between the *successful* and the *unmotivated* sub-groups of learners in motivational and emotional learning prerequisites and attitudes were the most obvious. During the learning session, these a priori-differences manifested themselves consistently in the form of clear motivational advantages for the learners with the "profile of success". Concerning learning prerequisites and motivational processes, conditions for successful learning were almost textbook-like for learners with this profile. Therefore, it is not surprising that this sub-group of learners clearly outperformed the other three sub-groups.

With respect to motivational and emotional learner characteristics, attitudes and especially experience in learning with computers, the profile of the sub-group with deficient prior knowledge allows positive predictions concerning knowledge acquisition. However, these favourable learning conditions obviously did not compensate for their considerable prior knowledge deficiencies. As a consequence, these learners were least successful in the post-test. These findings match with the strong prior knowledge-effect discussed above. Moreover, they once more emphasise the important role that domain-specific prior knowledge plays in complex learning.

Also in accordance with the findings discussed above, they underscore the importance of motivational and emotional learning prerequisites. In the present study, the influence of these often neglected dimensions was distinctly stronger than the effects of the instructional measures. However, it is clear that especially the cluster-analytical findings must be replicated by using bigger samples.

General discussion

In the present article, three empirical studies were discussed in which a web-based learning environment in the field of empirical research methods was investigated. On the one hand, the learning environment proved to be a learning tool which, in spite of it’s complexity and the high cognitive load it induced, proved to be effective and efficient. This was the case "objectively" and from the perspective of the students as well. In this sense, the main instructional goal of *NetBite 2* clearly was achieved.

However, since none of the additional measures proved effective, this achievement is only partly satisfactory. Neither the feedback guidance used in the first evaluation study nor the time-management measures used in the second study resulted in the expected effects. Incomplete solution steps and comprehension questions, which were investigated in the third study, also did not prove effective. All the additional measures without exception had been deduced both from theoretical considerations and empirical evidence. In addition, the concrete realisation of all measures had been guided by year-long teaching experience in empirical research methods. For these reasons, the findings are rather disappointing. All efforts to instructionally compensate for deficiencies in self-directed learning and to improve the quality of the learning behaviour failed!

On the one hand, one could blame the learning environment for being too complex and not adapted enough to the insufficient learning prerequisites of the students. On the other, however, one could blame the students for not exhausting the learning offerings within *NetBite 2*. Even for students with more favourable domain-specific learning prerequisites, the time-on-task the learners invested in all studies would have been far too short to learn optimally. Although both interpretations represent two sides of one coin and therefore have their own justification, they make it clear that the *problem of fit* between learning environment and learner (Stark, Gruber, & Mandl, 1998; Stark, Gruber, Renkl, & Mandl, 1998) has not been solved satisfactorily thus far. One symptom of this deficient fit is the fact that the students' perspective on the quality and intensity of their learning behaviour and the "objective" indicators of the learning behaviour and their evaluation by the researcher were nearly contradictory.

The need to improve the fit between students and demands of learning environments (e.g. Hartley & Bendixen, 2001) is further emphasised both by the prior knowledge and motivation effects of the second field study and by the cluster-analytical findings of the experimental study.

From a research perspective, it would be interesting to analyse the external validity of these results by using a different population of learners for which empirical research methods are of equal importance (for instance students of psychology or sociology). From a practical perspective, however, strategies to improve this fit have to be implemented urgently.

In order to achieve this practical goal, different strategies can be realised. Before the students start using the learning environment, they should be trained intensely and systematically to work on *NetBite 2* in combination with all aids and instructional measures offered. The short training implemented so far is clearly not sufficient. In this training, design principles of the *cognitive apprenticeship approach* (Collins, Brown, & Newman, 1989) should be implemented. For instance, the learners should be given the opportunity to observe a successful model. One important component of the model's interaction with the learning environment has to be effective feedback-processing, both in the context of incomplete solution steps and comprehension questions. Another important component should be the selective elaboration of instructional explanations.

In addition, *preparatory modules* of the learning environment should be developed which explicitly focus on supporting self-directed web-based learning in general and especially meta-cognitive competence of the learners. This module should be far less complex than *NetBite 2*; this could be realised by concentrating on *one* main topic in each module, for example, understanding the concept of correlation or interpreting results of variance analysis. In addition, the modules should be *adaptive*. The first preparatory module which concentrates on correlation concepts has already been developed and implemented in a recent experimental study (Stark, Tyroller, & Mandl, 2002). In this module, the adaptive component is realised in multiple ways: The learners not only have to choose if they want to work on special correlation tasks by studying pre-defined examples or by solving problems themselves. They also have to decide how many analogous tasks they need before they continue with working on types of tasks which are specialised on a new correlation concept. In order to increase the learners' mindfulness (Salomon & Globerson, 1987), they also have to give reasons for their decisions. The first evaluation results of this module have been very promising (Stark et al., 2002).

The integrative research paradigm by which the three studies were guided resulted in insights that are only partly favourable. But even the findings concerning the effectiveness of additional instructional measures are relevant from both a theoretical and a practical perspective. Amongst other things, these results show the limits of supporting complex learning. Therefore the application of this research paradigm can be highly recommended for further studies.

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