Pergamon

Learning and Instruction. Vol. 6, No. 1, pp. 77–93, 1996

0959–4752/96 $15.00 + 0.00

0959–4752(95)00017–8

FUNCTIONS, USE AND EFFECTS OF EMBEDDED SUPPORT DEVICES IN PRINTED DISTANCE LEARNING MATERIALS

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Abstract

In distance education, the design and elaboration of the learning materials are of prime importance. Despite the potential of new information technologies, printed learning materials are still the dominant delivery format. To support the learning process, the printed materials are enriched with "embedded support devices" (ESD), such as schemes, illustrations, examples, pre- and post-questions, tasks, margin texts, etc. Developers of learning materials assign functions and effects to these ESD. The validity of these assumptions has hardly been empirically researched in a distance education setting. In this article three studies are presented that focus on this issue. In the studies presented, three research methods are used to cope with methodological and theoretical problems as observed in earlier research in relation to ESD. It is concluded that ESD are used and appreciated by students and lead to better study results. The impact of individual characteristics of students was less clear.

Introduction

The Open university (Ou) of the Netherlands develops—to foster the independent learning process of students—sets of learning materials for distance education.† These materials are—still—mainly text based and printed. This type of independent learning materials gradually also influences educational practice in higher education in general.

In a distance education context there is hardly any face to face contact between students and teachers/tutors, so the learning materials have to be sufficiently supportive. Therefore an essential part of self study material consists of embedded support devices (ESD). The central role of embedded support in distance education can be illustrated by the fact that learning materials in this context consist of about 40% of ESD. ESD represent a set of formal and content-related

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†In the literature a variety of concepts is used: distance education materials, self-instructional texts, independent learning packages, learning resource packages, etc.

add-ons, extensions and elaborations of the printed materials, such as pre- and post-questions, schemes, illustrations, content pages, indexes, tasks, summaries, advance organizers, objectives, prior knowledge references and study guidelines. ESD aim at scaffolding the learning process. Course developers assume these ESD have certain functions and effects. We can distinguish three subsets of functions and/or effects:

- facilitation of the *access* to the content, e.g. by means of overviews, content pages, margin texts;
- facilitation of the *processing* of the content, e.g. by using advance organizers, activities, tasks, pre-questions;
- facilitation of the *testing of mastery* of the content/objectives, for example by embedding questions, by providing test-items with feedback.

Next to these rather "cognitive" functions and effects, ESD also substitute for the teacher roles by motivating students and invoking interest in new topics.

ESD are designed to evoke certain learning behaviours and as such influence study outcomes. In contrast to the fact that developers of distance education materials make intensive use of ESD and implicitly accept the effectivity of behaviours evoked by ESD, there is little empirical evidence to ground these functions and effects in a distance education context. Wade and Trathen (1989, p. 40), for instance, state: "despite of their popularity, there is no consistent empirical evidence that these techniques are any more effective than more passive methods of reading-only or repetitive reading". The question is whether ESD really fulfil the expectations of the developers: do they support the learner? Moreover, one can ask whether students in distance educational contexts really use ESD. And if they use them, how they are used. These are the core questions of the research reported in this article. To find answers to these questions, we first reviewed the literature on ESD-research. In a next phase, a set of research questions was defined.

Embedded Support Devices Questioned

Is the high investment in the design and elaboration of printed study materials worth the effort? A review of the literature is helpful to get an initial answer to this question.

A large quantity of the literature gives evidence of positive effects of ESD use in study texts. But, this research body has some important shortcomings. On the one hand we find methodological problems, on the other hand there are theoretical shortcomings:

- Most research focuses on single and isolated ESD, and this research is mainly not set up a "distance education" setting (see e.g. the reviews of Waller, 1979 or Rothkopf, 1970).
- Reviewing the research on ESD, it is striking that the ecological validity of the research contexts can be questioned. Studies are set up in laboratory-like settings sometimes with little relevant learning materials. Lockwood (1992, 1995) gives some clear examples of how poor ecological validity in many studies has led to results with little generalizability to real distance studying.
- The research reviewed hardly reports on what students actually "do" with ESD, the reports mainly focus on effects in terms of learning-outcomes. This is a problem in the research concerning effects of textbooks in "regular" teaching situations (e.g. Driscoll *et al.*, 1994) and certainly in distance education. Clyde and Crowther (1983, p. 4) refer to

this problem as follows: "Despite the growth of distance education, little systematic knowledge is available concerning the ways in which students use the distance learning materials provided to them". Researchers therefore call for a new research tradition in this research area; see, for instance, Lowyck and Simons (1991), Marland *et al.* (1990) and van Staa and van Meurs (1992). Research from a more recent "vintage" exemplify the emergence of this new tradition, e.g. the special issue on Comprehension of graphics in texts' of the journal Learning and Instruction (edited by Schnotz, 1993).

- Most research is linked to studies on reading comprehension, or on "learning from text" (see e.g. Elen, 1992). Generalizing findings from this research area to the more complex distance education context is not an easy task.
- If learners are presented with text-embedded support, it is not sure whether they use, or know how to use, these support facilities. We must not forget that the student—when studying the learning materials—has complete veto power over learning (Rothkopf, 1970; Winne, 1983). The research results by Winne (1983) confirm the suspicion that it is not easy to decide whether or not students use ESD. In his experiments he made use of placebo groups who studied text materials with ESD, but received no instruction as to how to use ESD. Up to 80% of the students did not use the ESD as hypothesized.
  In order to obtain more valid results, some researchers adopt alternative experimental treatments. Winne trained his students to use ESD (objectives, adjunct post questions). A similar approach is adopted by Bernard (1990) by incorporating processing instructions with the graphic organizers and structural cueing added to the study text. Also de Jong and Simons (1988) demonstrate how training in using ESD can enhance the learning process.
- Moreover, the question is not only whether students use the support devices or whether they know how to use them, but also if they need the support provided. Waller (1979) mentions different user objectives when dealing with study texts: entertainment, recapitulation/reviewing, browsing, studying in depth, searching for a particular item, etc. Each user perspective affects the potential effects/functions of ESD.
- Many researchers have questions about the implementation of ESD in distance education learning materials. Relevance and effectivity of them can be related to the quality of their implementation. This variable has hardly been controlled.
- There are theoretical problems with research done in this field. We observe a lack of a sound theoretical base, reductionist approaches and behaviouristic influences that lead to research in which potentially important variables are omitted. The ESD are considered as the key variables when explaining learning from text. But what about other possible intervening variables, such as reading comprehension, motivation, student characteristics, and characteristics of the task environment? At a theoretical level, this research weakness has strong implications: "If learners do not even respond to these stimuli, theories of instructional effects are well off their mark when they attempt to describe students' cognitive processes that mediate between instructional stimuli. (. . .) To date, the correspondence between how the theorists say learners use instructional stimuli and how learners actually use these stimuli in learning from instruction has been left largely to chance" (Winne, 1983, pp. 258–259).
- Meyer and Watson (1991) signal that if advice is derived from the research related to ESD, they are often not of practical value.

Towards a model

Considering the review of the research and our intention to set up studies in this field, we adopted the following approach. We first elaborated a model that integrates variables and processes that are considered to be of importance when studying from printed distance education learning materials, enriched with ESD. This eclectic model is used to bring together a variety of theoretical perspectives to ground the role of the specific variables or processes and to scan their potential interactions (Martens & Valcke, 1995). Secondly, research methods were reviewed to judge their relevance to be used in this field. In a next phase, the model, and methods selected, were used to direct our empirical research.

Learning from Text with Embedded ESD: a Model

Figure 1 depicts our model. It represents:

- The task environment: a major part of the task environment is operationalized by the availability of printed learning materials containing ESD.
- The student: cognitive and non-cognitive processes play a role in studying in the specific task environment. As regards the cognitive processes we differentiate between learning processes and reading processes. As non-cognitive processes we focus especially on motivation. Both cognitive and non-cognitive processes are influenced by a set of specific individual characteristics of the student (e.g. prior knowledge, educational background, gender, etc.).

The links between processes and variables in the model indicate potential interactions. For instance, the specific task environment in which printed learning materials are enhanced with ESD is expected to influence non-cognitive processes and cognitive processes. In relation to the latter a distinction can again be made between an influence on reading and learning processes. The role of individual student characteristics is important in the model. We assume that individual characteristics influence the way learning processes are influenced by the learning materials in the task environment. This implies that the effectivity of ESD is expected to depend on these individual characteristics.

In the following sections we discuss by means of short theoretical considerations and by summarizing briefly results of empirical research in relation to the basic processes and variables in the model (Martens & Valcke, 1995). As to the latter, we will refer as much as possible to research set up in distance education contexts.

The Learning Process

Learning processes take an important role and position in the model. These processes can be described/explained by using existing theoretical approaches. We adhere to information-processing approaches, such as elaboration theories, schema-based theories, etc. In particular, we make use of the Sternberg view (1986, 1988, 1990) to build up this part of the model.

Cognitive functioning—according to Sternberg—can be described by means of a set of "components". A component is "an elementary information process that operates upon internal representations of objects or symbols" (1986, p. 225). Sternberg distinguishes metacognitive, performance and knowledge acquisition components.

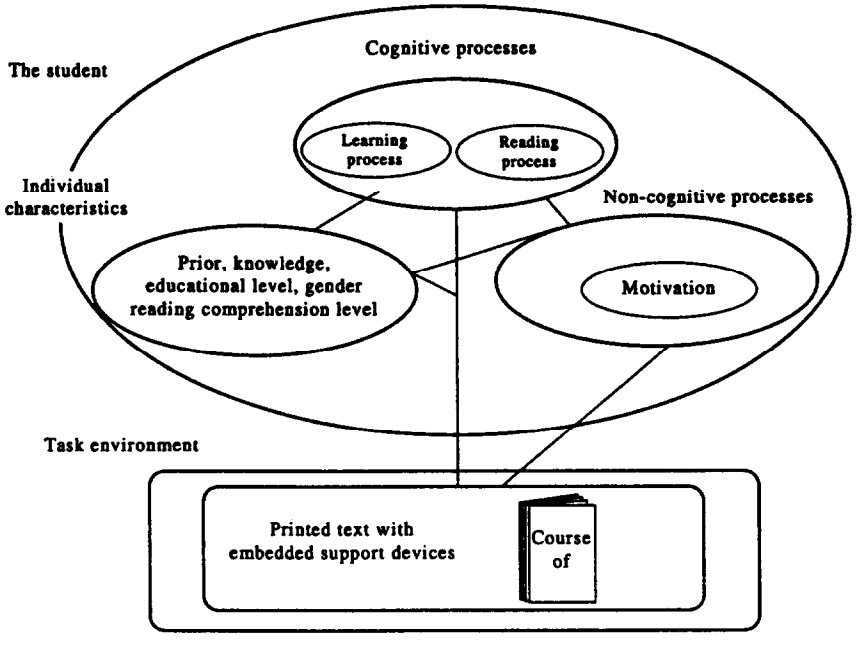

Figure 1

In an earlier study, we could relate—at a theoretical level—these "components" to functions and effects of specific embedded support devices (Valcke *et al.*, 1993). The study made more explicit the link between ESD and specific components of cognitive functioning. But an empirical part of the same study did not succeed in validating *in extenso* the hypothetical functions and effects.

Considering the learning process, the impact of individual differences is evident. In the literature, an abundant list of variables can be found. In our model, we especially focus on prior knowledge differences. Prior knowledge is considered to be the determining factor in learning processes (Ausubel, 1968; Entwistle & Waterston, 1988). There is plenty of empirical evidence that supports this view (cf. Dochy, 1992).

The Reading Process: an Intervening Process

Since we focus on studying from printed learning materials, we have to consider the impact of the reading process. We only focus the reading process as it is related to the learning process (Martens & Valcke, 1995).

Non-cognitive Aptitudes: Motivation

When working with adults in a distance education context it is expected that motivation is high. In the researches presented here, we will not explicitly test the motivation of students.

Individual Variables

Next to individual characteristics explicitly related to either reading comprehension or the learning process, other individual differences between learners can influence the processes investigated in this study. Examples are: attitudes, experience with distance education, learning style, etc.

The potential impact of a large set of these variables has already been researched in earlier studies at the Dutch Open university (Valcke *et al.*, 1993). In a study, based on structured interviews with law students, it was first of all found that the use of ESD is related to positive learning outcomes. But, even more important was the finding that the use of ESD was influenced by specific individual student characteristics, such as gender, educational background, prior knowledge, etc.:

- women are more likely to use ESD at a deep level. Deep level refers to reading for comprehension (e.g. Marland *et al.*, 1990);
- highly educated people are more likely to use ESD at a deep level;
- students with low prior knowledge of governmental law are more likely to use testing ESD at a deep level;
- students who use study guidance are more likely to use testing ESD at a deep level.

Towards a Research Set-up

We preferred to organize a set of different studies, each of them based on the use of a different research instrument and approach: eye-movement registration, questionnaires, and the measurement of product outcomes (effect study). Some methods require introspection which may affect reliability and validity. Others do not but these methods provide less information. This variety is in our opinion helpful to obtain reliable, valid and, in particular, generalizable results.

Research Hypotheses

Is the high investment in the design and elaboration of ESD in printed study materials worth the effort? This general research question was translated into the following set of research hypotheses.

H1 Students use ESD when studying from text in a distance education setting.
H2 Making use of ESD is related to positive learning outcomes (higher scores on tests or tentaminations and/or different speed of study).
H3 Individual differences play a role in relation to the use of ESD and the functions and effects assigned to them.
H4 Students appreciate the availability of ESD in printed learning materials for distance education.

Depending on the research method used, special attention will be paid to subsets of these hypotheses. In the next three sections of this article, we focus on each specific set-up. The presentation of the research results is structured along the research hypotheses.

Research with Eye Movement Registration

Eye-movement registration is a method to map the attentional focus of a subject when reading. Very reliable and valid results can be obtained. But the method also presents specific difficulties. There is for instance scepticism about the theoretical interrelation between eye-movements and higher order processes.

The method is used to test one single hypothesis: Students use ESD when studying from text in a distance education setting. For this purpose, the method is powerful in view of the unbiased, objective nature of the data obtained.

Interpretation of Eye Movement Patterns and Characteristics

Conclusions in relation to this single hypothesis will be derived from data in relation to characteristics of the reading process when reading text-parts containing ESD. We expect, depending on the function of an ESD, that some are read shorter than the average text and others are read during a longer period of time. These differences in reading pattern are interpreted as indicators of deep level use of ESD. Differences in reading pattern are expected to occur in the total reading time and reading time per word:

- longer total reading times and reading times per word are expected when reading the ESD: learning objectives, text "highlighted" by margin texts and questions;
- shorter values are expected when reading the ESD: content page, introductions, examples and summaries;
- the ESD "feedback on questions" is expected to invoke no significant different values in reading behaviour parameters.

Research Sample

Eleven first year law students, studying at the university of Maastricht, participated in this research. These students are used to study independently with distance education materials. From the results of a prior knowledge test on "Governmental law" it was concluded that all students had comparable prior knowledge on "Governmental law". Due to technical problems during recording, the data of one subject could not be used for further analysis.

Research Method and Instruments Used

The apparatus to register eye movements was developed by a team of Ou-researchers (Stolk, Smulders & Pelsmaekers, 1991). The set-up implies that students sit in any easy seat. Eye-movements are followed with an invisible infra-red beam, allowing students to move their head relatively freely. The sessions were videotaped.

During the introduction to the experiment, students were instructed to study a learning unit of the course "Introduction to Governmental Law" in order to take a test at the end of the session. A substantial set of ESD was implemented in this learning unit.

During the research session, the pages of the learning unit were projected in front of the

student. The subject could control this projection with a remote control. Learning was self-paced. Going forward or backward was allowed. After the session, a comprehension test was administered. During a short interview, students responded to questions about the research set-up.

Analysis Techniques

The data registered were analyzed with the computer programs "ANALEYES" and "EYE-CATCHER" (Stolk *et al.*, 1991). The complete reading process could be reconstructed and screened. Figure 2 displays the result of such a chronological reconstruction on the screen. With a high degree of accuracy one can control what text part the subject did look at during what period of time. The black dots in Fig. 2 represent "fixation points". The bigger the dot, the longer the fixation.* The rectangles represent the text blocks of two pages in the course. The polygon (upper right part) represents a scheme in which relations discussed in the text are visualized.

Each page continued ESD in well-defined areas. The attentional focus of these areas was the unit for the further analysis. Characteristics of the reading process of areas containing ESD, were compared to the general mean. For each area the Eye-Catcher-program produced a set of values:

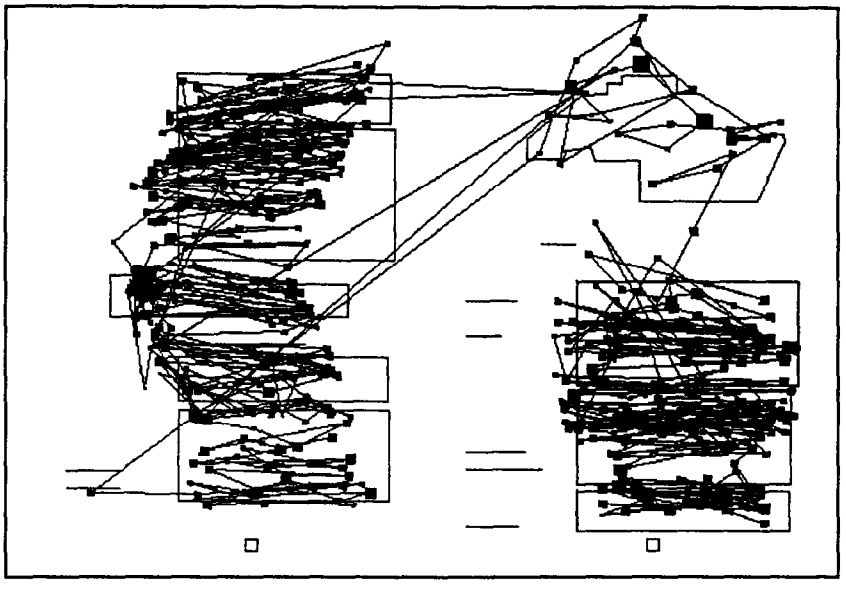

Figure 2. Pattern of eye movement during studying two pages of a law course

*In this study fixation length and number of fixations were not used for analysis, since we aimed at presenting whole pages which implies that single fixation measures are not adequate. The analysis was not aimed at single words but at text parts such as paragraphs.

the total time needed to read the text in this area, in milliseconds; the average time to read one word in milliseconds.

For the ESD "schemes", it is not relevant to make comparisons with the rest of the text. Therefore another reading parameter was defined: the number of "leaps". When students read/study "schemes", they "leap" to other text parts and back to the scheme.

Results

H1 Students use ESD when studying from text in a distance education setting.

To examine if all ESD were read/studied by the students, the data for each individual in relation to each area with a ESD were checked. The analysis reveals that all ESD had been read/studied at least once by every student. Control of the individual data also demonstrates that there are interesting differences in reading/study approach. Some students tend to reread while others read the ESD only once. Because of the small sample size no comparisons were made between subjects.

Table 1 presents the mean parameter values of the students. The table is helpful when comparing the reading/study behaviour of the students when dealing with areas with or without ESD. On average, students spent 360 milliseconds to read words in areas with ESD and 327 milliseconds to read words in the standard texts. This difference is not significant.

In the Table 1, the column "sign" indicates the results of the reading time/word of text containing ESD as compared with the average reading time per word (344 milliseconds). A positive sign in this column indicates that the reading time per word is longer and a negative sign indicates the opposite. To this comparison the results of a nonparametric sign test (binomial test) are added. However, looking for statistical significance levels is probably not the best

Table 1
Reading Times Per Word and Binomial Test (One-tailed Analysis, for Feedback 1 and 2: Two-tailed Analysis)

	Area with ESD				Area without ESD (standard text)		
	Number of words	Total reading time	Reading time per word	Binomial test, sign	Number of words	Total reading time	Reading time per word
Content page	39	6238	124	−**	40	14244	356
Introduction	50	9086	159	−**	52	14262	274
Learning objectives	101	52432	519	+	109	57096	523
Margin text 1	56	26900	480	+	70	21366	305
Margin text 2	40	12426	311	−	44	9796	223
Example 1	166	42672	257	−*	168	45692	272
Example 2	75	23578	314	−	85	31002	364
Example 3	134	41082	307	−	132	46938	356
Question 1	29	18788	648	+	33	9729	295
Question 2	40	22160	554	+	43	6951	162
Summary	92	25678	279	−	92	35464	385
Feedback 1	102	32998	323	−	100	36500	365
Feedback 2	104	42518	409	+	100	36500	365

*p <0.05; **p <0.01.

way to proceed in this type of research, with small sample sizes. A more qualitative approach, looking at patterns, seems more suitable. The pattern of results is in line with our expectations:

questions and text emphasised by margin texts invoke higher values;
content page, introductions, examples and summaries invoke shorter values;
feedback produces both a positive and a negative effect.

The support device "learning objective" evokes a reading pattern different than expected (shorter reading times instead of longer).

As stated earlier, schemes have to be dealt with in a different way. Schemes are expected to invoke "jumps" towards other text and back. The three schemes in the learning unit analyzed invoked on average 3.7, 2.5 and 4.5 leaps.

The influence of the research set up was investigated by comparing the tests scores of the experimental group with a control group of 18 subjects who studied the same material from a printed version. No significant differences between the two groups were found on the comprehension test, reported use of ESD or students' ratings of the "learning access level" of the materials presented.

Research with Questionnaires

At the Open university of the Netherlands, an annual Ou-evaluation study involving about 2000 students is set up by the department OID (Research and Information). In 1992, part of the questionnaire centred on ESD (van Staa & van Meurs, 1992). These questions focused on the impact of ESD-use on learning outcomes, the role of individual differences and students' appreciation of ESD (hypotheses 2, 3, and 4). To test hypothesis 4, the data were linked to the Open university student-database (BASIS), containing a large set of student information.

It was impossible to link the ESD-related questions to specific courses studied by the students. We therefore could not ask whether specific ESD had been used. Being aware of the limitations of this approach, no attempts were made to check the first hypothesis about the actual use of ESD when studying from text in a distance education setting. As a consequence, hypotheses 2 and 3 do not build on the variable "use of ESD", but on the variable "appreciation of ESD'.

Research Sample

As stated above 2000 Ou-students, selected in a systematic way from the Ou-student population (n=55.000), were involved in the 1992-evaluation study. Student response was 1159 (58%) and a weighting procedure was used to correct for systematic errors in the response group (van Staa & van Meurs, 1992). The further analysis only included a subset of students (n=853), who indicated to have studied a substantial part of the course (at least 50 per cent of the course) (Martens *et al.*, 1993).

Analysis of the Results

The data were analyzed by means of descriptive statistics and correlation/regression analysis.

H4 Students appreciate the availability of ESD in printed learning materials for distance education.

Students highly appreciate ESD; 93% of the students disagree with the statement "I prefer printed study materials without ESD so that I can structure the material myself". Only 7% of the students prefer course materials without ESD. The high appreciation of ESD is reflected in the level of support the students report in relation to specific support devices. Students were asked to quantify this "level of support" on a scale from 1 to 5 (1=low, 5=high). Table 2 represents the average level of support students feel they get from the embedded support devices. The results reflect the overall high appreciation of ESD.

We controlled whether there is an interrelation between the study domain* of the student and the degree of appreciation of ESD. The appreciation of ESD seemed to be significantly different for students studying courses in the cultural science domain. Cultural science students appreciate ESD less (r=0.24, p<0.001).

H2 Making use of ESD is related to positive learning outcomes (higher scores and/or different speed of study).

No significant relation was found between the appreciation of ESD and study success (defined as the number of study credits per year) (r=0.06). Take note of the fact that we could not investigate the interrelation between ESD-appreciation and learning outcomes for a specific course.

Research on Courses Variants

Here we tried to study ESD by measuring product outcomes of studying different elaborations of the learning materials: a course variant with and a course variant without ESD. In this study a large set of student characteristics was taken into account, such as reading comprehension level, prior knowledge state level, educational background, gender and time management.

Table 2
Average Level of Support of ESD Reported (1 = Low, 5 = High)

ESD	Average	σ
Margin texts	3.3	1.2
Titles	3.1	1.4
Questions	3.6	1.2
Tasks	3.6	1.2
Content pages	2.7	1.4
Schemes	3.5	1.2
Repeat units	3.8	1.2
Study guidelines	2.9	1.5
Examples	3.7	1.0
Final test examples	4.1	1.0

*These methods of **rereading, planning an approach** using information given, **checking your plan**, and **checking calculations** help to solve the problem.

This study focused on three aspects of ESD: the use of ESD, the effects of ESD and the role of individual differences in the relation between ESD and learning outcomes.

Research Sample

A group of 36 first year law students (20 male and 16 female), studying at the university of Maastricht, participated in this research. These students have considerable experience in studying independently with distance education materials.

Course Variants

The study was based on a representative learning unit of the course "Introduction to Governmental Law" with an expected study load of about 4 hours. Two variants of this learning unit were elaborated: an "extended" and a "short" version.

The "extended" version resembles the original elaboration published by the Ou, comprising a large set of ESD. Only a few adjustments were made to the content to make it possible to study this learning unit independently from the rest of the course.

In the "short" version nearly all ESD had been omitted. In eliminating the ESD, care was taken not to affect the coherence of the content. ESD that were of importance to conserve the coherence of the study text or that contained basic information were not removed. A domain expert assisted the researchers in this procedure. The elimination resulted in a 6-page reduction of the 15-page long text. The following ESD have been removed: content page (1), learning objectives (1), text in italics (12), margin texts (24), schemes (3), examples (11), summary (1), feedback (4), question (4).

Research Instruments

Research instruments were used to measure on the one hand product outcomes (a comprehension test), and on the other hand to register individual student characteristics (a reading comprehension test, a prior knowledge state test and a questionnaire).

A new reading comprehension test was developed to determine the reading comprehension level of the students. A new test was developed since a review of existing instruments did not result in an appropriate test. The experimental version of the reading comprehension test consisted of 29 items (Cronbach's alpha = 0.68).

The comprehension test and the prior knowledge test consisted of subsets of items, depending on the mastery level they tested: knowledge or insight (knowledge refers to reproduction and insight refers to deep level processing).

The questionnaire consists of three subparts (A, B, C). Part A was helpful to determine general student characteristics such as age and gender. Part B consisted of questions that helped students to judge how easy it was to study a particular course variant. This information was used to define a value for the "Learning Access Level" (LAL) of a course variant. Part C contained specific questions about the use of ESD. Only students who studied the extended course variant answered part C of the questionnaire.

Research Method

Prior to studying the course variants, the reading comprehension test, the prior knowledge state test and part A of the questionnaire were administered. The results of the prior knowledge state test were used to match two groups of students for the research session.

Two weeks after the first session the students were invited to participate in the research session. 18 students studied the "extended" variant of the learning unit; the other 18 studied the "short" variant. Study time was restricted to the predefined study load of 4 hours. The students were informed that they were expected to study the content in order to solve a comprehension test. Students indicated when they had finished studying. The time spent by the students was recorded. After this study session, students solved the comprehension test and filled in part B and C of the questionnaire.

Results

H1 Students use ESD when studying from text in a distance education setting.

Students indicated whether or not they did use specific ESD when studying the learning unit. Table 3 gives an overview of the proportion of students that indicate they use specific ESD.

The reported high level of ESD-use can be considered as a sound base to check the second hypothesis that potential differences between course variants in learning outcomes of students are due to the use of ESD.

H2 Making use of ESD is related to positive learning outcomes.

Analysis of variance was used to check whether studying different course variants resulted in significantly different product outcomes. This analysis was based on the specific subsets of items measuring the mastery at "knowledge level" (reproduction) or "insight level" (deep level processing). The results of this analysis are reported in Table 4. To these results we added some further measures, such as the time used by the students and their appreciation of the Learning Access Level (LAL).

From Table 4, we can conclude that students studying the version with ESD obtain higher scores on the comprehension test. This difference is significant for test items measuring mastery at insight level.

Table 3
Use of ESD (n = 18)

ESD	Used by % of students
Margin text	100%
Schemes	100%
Example	94%
Feedback	94%
Task	94%
Learning objectives	89%
Summary	89%
Text in italics	89%
Content page	83%

Table 4
Analysis of Variance on Product-outcomes Between Groups of Students Studying Two Course Variants (n = 36; one-way analysis)

Variable	Average short version	Average long version	Degrees of freedom	F-value
LAL	46,17	46,50	1 ; 34	0.024
Time (in minutes)	46,50	51,56	1 ; 34	0.901
Insight	6,44	7,56	1 ; 34	3.47*
Know	8,00	8,28	1 ; 34	0.167

*p <0.05.

This positive effect is not due to a longer reading time of the text with ESD. Although the text without ESD was about 40 per cent shorter, no significant differences in average reading time are perceived between the two groups of students studying different course variants. It was also surprising that no significant differences were found in students' ratings of the Learning Access Level (LAL).

H3 Individual differences play a role in relation to the use of ESD.

In Table 5 the results of the univariate analysis of variance are presented. The aim of this analysis was to investigate if students with certain characteristics (e.g. high prior knowledge) benefit more from a certain course variant. No significant interactions with student characteristics were found.

Discussion

When summarising the research results from the different studies, the following picture, that will be discussed below, emerges:

- students make use of ESD to a high extent;
- using ESD positively influences study outcomes (except for study credits per year);
- the use of ESD does not seem to be related to individual student characteristics;
- students appreciate ESD in learning materials.

Table 5
Interaction Effects with Time or Insight Questions with Course Version (d.f. = 1,32; two tailed)

	F
Dependent: time	
Version * prior knowledge	0.190
Version * reading Comprehension	3.57
Version * gender	0.653
Dependent: post-test insight	
Version * prior knowledge	0.036
Version * reading Comprehension	0.133
Version * gender	0.052

This summary suggests the acceptance of the first hypothesis "students use ESD". A striking finding is the fact that making use of ESD does not extend the time needed to study the materials.

In line with the first hypothesis, the fourth hypothesis can be accepted as well. The high appreciation of ESD is consistently found in the studies reported.

The picture is less clear when considering hypothesis two. We used several variables to measure study outcomes: credits per year, scores on post test and study time. The study with the course variants suggests accepting the hypothesis when focusing on the level of insight students gain from the learning materials enhanced with ESD. This is in line with previous research based on interviews (Valcke *et al.*, 1993). But, in the research based on questionnaires, no clear interrelation was found between ESD-use and study outcomes. This might be due to the fact that the questions did not focus on the study of a specific course. Moreover, the "appreciation of ESD" and not the actual use of ESD was used as a measure. Surprisingly text with ESD did not result in longer reading times. Apparently the short version without ESD was more difficult to understand, which led to longer reading times of the "basic content" in the version without ESD.

As a consequence, we tentatively accept these three hypotheses. Accepting these hypotheses implies that some major criticisms against the effectivity and/or efficiency of ESD, raised by some researchers (e.g. Marland *et al.*, 1990; Vermunt, 1991) can be answered.

The third hypothesis could not be confirmed. The impact of individual student characteristics remains less clear, in contrast to our research model that clearly indicates their importance. This also contrasts with our preliminary research findings that were based on interviews, where we could illustrate the impact of student characteristics such as educational level, gender, prior knowledge and use of study guidance (Valcke *et al.*, 1993). This might in part be due to the instruments used to measure student characteristics. But, and this is probably a more valid explanation, all students used ESD to a very high extent. This makes it less easy to find differences in use and/or appreciation of ESD among different "types" of students. A final explanation can be linked to the quality of the ESD as implemented in our experimental research materials. They were borrowed from existing Ou-learning materials and, as a consequence, had not been designed with the needs of different types of students in mind. Moreover, it is conceivable that it is relevant to provide students with alternative elaborations of the same ESD; e.g. examples in a statistics course differ according to the diploma line of students, students studying economics or social sciences get other examples, tasks, etcetera, linked to their knowledge domain.

Conclusions

This latter line of thinking when it comes to the use of ESD, introduces a meaningful and new direction for future research. This new direction is no longer based on ready-made printed learning materials, but rather builds on the potential of interactive learning environments, where the student can influence the availability and/or design of specific ESD. Interactive, electronic course variants help to meet individual needs and preferences.

Currently, research in this field is already carried out at the Open university of the Netherlands. An Interactive Learning and Course Development Environment (ILCE) has been developed (Valcke *et al.*, 1994). Developers of distance education materials are making use of the system to design flexible learning materials where the courses—at content-level and at the

level of the ESD—are adapted to the needs of the students. Also experience is built up by studying students working in these interactive learning environments, where they actively influence the type, elaboration and availability of specific ESD. This on going research is in line with the research reported here. It builds on the use of ESD, their impact on study outcomes and might—in future—be helpful when attempting to understand the interrelation between student characteristics and ESD-use in distance education learning materials.

Our final goal with this research is to provide students with a new generation of learning materials, in line with the characteristics of demand-driven education and in contrast to the traditional "supply-driven" paradigm (Kirschner & Valcke, 1994). In our view it is a way of adapting and optimising course materials to the needs of individual students in a distance education context (Martens, Valcke & Portier, in press).

Despite the problems mentioned above, we think that two conclusions can be drawn that are relevant for developers of course materials: firstly use ESD in course material. The implementation of ESD can improve the readability of study texts without affecting the coherence or consuming study time. Secondly: instruct students to use ESD and instruct students how to use these ESD.

Acknowledgements — The authors wish to thank M. Smulders and J. Stolk of the Faculty of Technical Sciences, who have been of great help in the data collection phase with Eye-Catcher. We also thank W. Voogt of the faculty of Law Sciences for his support and A. van Staa and C. van Meurs of the department OID for their collaboration in the further analysis of data from their annual Ou-evaluation study.

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