DOCUMENT RESUME

ED 383 745 TM 023 265

AUTHOR Martens, R. L.; And Others
TITLE Comparing Study Outcomes from Different Learning Environments for Statistics. OTIC Research Report 65.
INSTITUTION Open Univ., Heerlen (Netherlands). Centre for Educational Technological Innovation.
REPORT NO ISBN-90-358-1411-8
PUB DATE 95
NOTE 25p.
AVAILABLE FROM Open University, Centre for Educational Technology and Innovation, P.O. Box 2960, 6401 DL Heerlen, The Netherlands (20 Dutch guilders).
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *College Students; *Distance Education; Educational Environment; Foreign Countries; Higher Education; *Individual Differences; *Interaction; Lecture Method; Outcomes of Education; Printed Materials; Reading Comprehension; *Statistics
IDENTIFIERS Belgium; *Embedded Support Devices

ABSTRACT

In this report, the effectiveness of prototypes of interactive learning environments (ILEs) is compared with printed learning environments or traditional face-to-face lectures. The learning content for all conditions was a course on inferential statistics for first-year college students. In the learning materials, a clear distinction was made between the basic content and embedded support devices (ESDs) that are expected to support learning. The prototypes differed in the extent to which they supported interactivity in manipulating the ESD and the degree of discernability of the ESD. In a large empirical study involving 502 Belgian college students, ILEs were compared with learning environments based on printed materials and traditional lectures. Results indicate that there are no differences in learning outcomes when the conditions are compared. They also show the role of ESDs and the significant aspects of individual differences among students on study outcome. Three tables summarize study findings. (Contains 36 references.) (Author/SLD)

Comparing study outcomes from different learning environments for statistics

R.L. Martens

S.J. Portier

M.M.A. Valcke

Onderwijstechnologisch Innovatiecentrum OTIC
Open universiteit

Comparing study outcomes form different learning environments for statistics

OTIC Research Rapport 65

R.L. Martens

S.J. Portier

M.M.A. Valcke

Acknowledgements
The authors wish to thank H. De Keyser, K. Goeminne and G. Schuyten of the University of Gent, Faculty of Psychology and Educational Sciences, Department of Data-analysis and J. van Buuren form the faculty Social Sciences of the Ou for their active participation in this study.

OTIC RESEARCH REPORTS.

The Open university is responsible for developing and offering open, higher distance education in which special attention is paid to innovations in educational technology. The research in this field is concentrated in OTIC, that is the Centre for Educational Technology and Innovation (Onderwijstechnologisch Innovatie Centrum).
OTIC is also engaged in running projects for other institutes. Here the Centre makes use of OTIC's knowledge and experience acquired in research and development.
The series of OTIC Research Reports consists of publications of the OTIC research projects and aims mainly at an audience of fellow researchers.

RESEARCH PROJECT 'ILCF'.

At a general level the ILCE-project aims at designing, developing and researching a computer-based system to support the process of designing, producing and exploiting distance education learning materials. All sub-processes are supported in an integrated environment and all materials, whatever their data type (text, sound, pictorial or video) are processed and stored digitally. The research & development activities have resulted in the following types of outcomes:

- Six prototypes of subparts of the ILCE-system adopting a Object Modelling Technique (OMT);
- A comprehensive ILCE-system that integrates the multiple facilities outlined above;
- Evaluative details, based on experimental or quasi-experimental set-ups with prototypes;
- Analyses of the state of the art, strength-weaknesses of the current course development procedures.

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Martens, R.L.
Portier, S.J.
Valcke, M.M.A.

Comparing study outcomes form
different learning environments
for statistics

- Heerlen: Open university
Centre for Educational Technology and Innovation (OTIC)
- Ill. -(OTIC research report 65)
Met lit. opg., reg.
ISBN 903581411 8

Reference: distance education - support - interactive learning

OTIC Research reports are avialable from:

Open Universiteit
Secretariat OTIC
Postbus 2960
6401 DL Heerlen
Telephone 045-762317 (-2772)

Content

Abstract

In this research report the effectivity of prototypes of interactive learning environments (ILE) are compared with printed learning environments or 'traditional' face-to-face lectures. The learning content is the same for all conditions: a course on inferential statistics for first year universitary students. The computer-based and the printed environments are used for independent learning. In the learning materials, represented in the prototypes, a clear distinction is made between the basic content and embedded support devices (ESD) that are expected to support learning. The prototypes differ in relation to the extent they support interactivity in manipulating the ESD and the degree of discernability of the ESD. In a large empirical research set-up ILE are compared with learning environments that are based on printed learning materials and a control situation with face-to-face lectures. The results indicate that there is no difference in learning outcomes when the conditions are compared. They also show the role of the ESD and the significant impact of individual differences between students on study outcome.

1 Introduction

This research report is based on the results of a collaborative study between the Open university of the Netherlands (Ou) and the University of Gent, Belgium. This reports presents a comprehensive part of this research. Among other aims, the study conducted focuses on the evaluation of interactive learning environments (ILE) to support independent learning. For an extensive overview of the study we refer to Martens, Portier, Valcke, Van Buuren, Dekeyser, Goeminne & Schuyten, 1995, a, b).

1.1 Background

In higher education there is growing need for more (cost)effective educational techniques such as independent learning. Often budgets for eduction are cut while drop-out rates among students are too high. This is certainly the case for 'difficult' subjects such as statistics. In an attempt to make education more effective and to be able to handle larger numbers of students, a research was carried out to investigate if independent learning is a good alternative for traditional face-to-face lectures. These lectures cost relatively much time from professors and from students (for instance because of travelling time). There is a growing pressure or institutes for higher education to increase the quality and decrease costs per student (van Driel & van den Berg, 1994; Segers, 1993). By researching techniques for making higher education more effective, this study aims and contributing to this issue.

In this research report we concentrate on design characteristics of ILE and printed materials in relation to student use of support in ILE and student characteristics. As will be briefly discussed in the theoretical base of this study, student control over the learning environment is considered to depend on specific student characteristics (cf. e.g., Esichaikul, Smith & Madey, 1994; De Diana & Van der Heiden, 1994). Design features have to take this into account.

To measure the effectivity of the ILE, three prototype-versions are used in a research set-up. Moreover, two alternative learning environments based on printed learning materials (PLE, printed learning environments) and a control setting with lectures are incorporated into the research design. The learning environments are researched with university students taking a statistics course. This course focused on 'inferential statistics' which is a part of an Ou-course for the social sciences.

1.2 Learning materials to support independent learning

The Ou sets up education in a distance education setting. Thus far, the delivery of education is mainly based on printed learning materials. The Ou has invested a lot in enhancing the quality of the learning materials to 'embed' all kinds of support to help students during their study. The didactical elaboration, embedded in the learning materials is supposed to take over the supportive role of a teacher who is normally present during a lecture or a working group.

Considering the independent learning setting, the high-quality elaboration of the learning materials is of prime importance to support a learning process:

- We distinguish in the learning materials on the one hand 'basic content' that reflects the domain specific (scientific) information and on the other hand embedded support devices (ESD). Given the large amount of ESD in learning materials, these are clustered according to their basic functions and effects as suggested by Valcke, Martens, Poelmans and Daal (1993):
  - *orienting ESD*: learning objectives, references to other learning materials, references to required prior knowledge, and use of history.
  - *processing ESD*: additional learning materials, advance organizers, figures, glossary, introductions, study advices, summaries, tables, examples, extended learning

materials.
- *testing ESD*: self-test items, exercise items (on know, insight and apply-level), answers.

- ESD are integrated into the basic content where course material developers consider them to be of relevance. Taking account of our theoretical base (see below) and earlier empirical studies (e.g., Portier & Van Buuren, in press), the level of integration into the basic content is considered to be an important variable. Therefore, we distinguish between learning materials in which ESD are hardly discernable and learning materials where the ESD are explicitly discernable or identifiable. Discernability of support devices may have an important impact on the way students use the material because with discernable ESD students can decide in advance to use or to skip ESD, whereas in the other mode the ESD has to be read. But discernability might also interrupt the visual coherence of the study material and hinder the study process.
- In printed learning materials, ESD are available depending on the design-decisions of the learning material developers. In interactive (electronic) learning environments, we transfer the decision and responsibility to incorporate ESD into the basic content to the student. In our theoretical base, this means that the degree of 'interactivity' is considered as a basic feature of the learning environment. In the research set-up, this is reflected into sets of experimental conditions where two basic delivery modes are distinguished: printed delivery and interactive delivery.

The explicit distinction between basic content and ESD, the level of ESD-discernability and the degree of interaction in manipulating ESD form the main objectives of the present research. Previous research has shown that use of ESD leads to better study results. But can they 'replace' a teacher? With this research we hope to gain more insight in this matter.

2 Theoretical background of the study

Our theoretical base positions learning with ILE in a framework of interrelated processes and variables. The instructional design model of Snow and Swanson (1992) is helpful to describe this theoretical base. These authors define the following interactions (represented by '*') between variables and processes:
*aptitudes * learning types * content domain * instructional design * situations * populations*
Applying this matrix to our research, we get the following:

aptitudes:	cognitive and non-cognitive (motivation) aptitudes
learning type:	independent learning in interactive or printed learning environments
content domain:	statistics in social sciences
instructional design:	learning materials where ESD are separated from the basic content
situation:	independent learning
population:	adult students

Depicting this matrix results in the following theoretical model to describe and explain independent learning based on ILE (Figure 1):

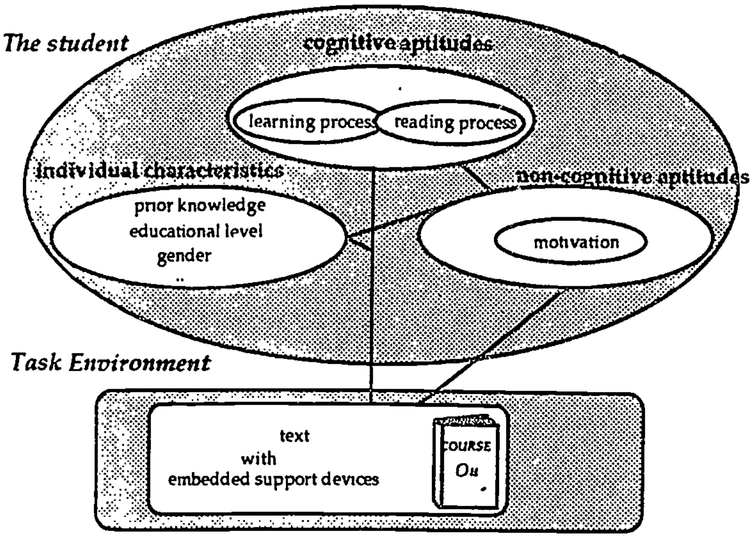

Figure 1 A model for independent learning.

2.1 Elements of the model

This model comprises:

- COGNITIVE APTITUDE related to LEARNING as described by the three-component theory of Sternberg (1986). This cognitive psychological theory is helpful to describe cognitive processes related to learning. In earlier studies we have described how this theory can be related to the functions and effects of ESD in learning materials (Valcke, Martens, Poelmans, & Daal, 1993).
- COGNITIVE APTITUDES related to READING. Since the textual representation of the learning materials is still a predominant representation mode, even in ILE, reading comprehension is an important process. The focus is on discourse comprehension and not on the decoding processes. In our model, reading comprehension is considered as a basic process related to the learning process, but also as an individual variable that interacts with the other variables and processes in the model.
-The influence of the NON-COGNITIVE APTITUDE motivation. For example Ames and Ames (1984) have indicated the overall importance of motivation in relation to learning. Also in the context of independent learning and the specific design of learning materials, authors refer to the central role of motivation. Waller (1979) points out at motivational effects of typographic access structures for educational texts. Elshout-Mohr (1991), Van Hout-Wolters and Willems (1991) mention that motivation can be enhanced by presenting a specific set of ESD, such as objectives, questions/tasks, examples, introductions, feedback, content pages and structure pages.
Considering the specific task environment, also the 'attitude towards learning with computers' is a relevant variable.

- The LEARNING MATERIALS that are used as input for the learning process (basic content + ESD). In the research literature, a vast set of theoretical and empirical studies help to base the functions and effects of embedding support devices in learning materials. Also at the Ou various research projects and studies have been set up (Valcke, et al., 1993; Martens, Poelmans, Daal, Valcke & Stolk, 1994; Martens, Poelmans, Daal, Van Staa & Van Meurs, 1993; Martens, Poelmans, Daal, & Valcke, 1993; 1994). In general it was found that ESD in PLE are highly used, appreciated positively and lead to better study results.
- The TASK-ENVIRONMENT: the interactive learning environment. An interactive learning environment is defined as a *context* that supports learners to *interact* with a *knowledge base* in order to attain clearly defined learning objectives. Support is especially realised by the possibility to *adapt* to the individual learner.
ILE as conceptualized in our research are related to a variety of instructional technology applications. There is for instance a strong relationship with Hypercourseware[1] when the focus is on learner control and the availability of a large knowledge base (cf. Mayes, Kibby & Anderson, 1990; Thompson, Simonson & Hargrave, 1992). ILE have analogies with 'microworlds' and 'ILE' as defined by Lawler (1987) when we concentrate on the active exploration and manipulation of a rich knowledge base. Also, ILE have a strong connection with (Intelligent) Computer Assisted Instruction, Adaptive Learning Environments (Jones, 1992) and (Intelligent) Tutoring Systems (McCalla, 1992) when the focus is on the adaptive qualities (Larkin & Chabay, 1992).
ILE resemble Computer Managed Learning systems and especially the emerging Interactive On-Line Advisory systems when we consider the 'adaptive' possibilities of the system.
- INDIVIDUAL VARIABLES that interact with study behaviour and the way the learning environment is used and processed. In the present research report we focus on a subset of individual variables: reading comprehension, prior knowledge and use of ESD. The variable reading comprehension has already been discussed. The second variable refers to the prior knowledge a student already has before starting the learning process. Many authors have indicated the importance of this variable (e.g., Ausubel, 1968; Mayer, 1979; Dochy, 1992; Dochy & Alexander, 1995). Dochy (1992) reveals in this context the multi-dimensional nature of prior knowledge. In our research we will for instance make use of the distinction between the behavioural and knowledge dimension in prior knowledge. The former refers to the 'mastery' level a student can perform in relation to a specific body of knowledge (knowing, insight in, application). The latter refers to the specific 'type' of knowledge he or she masters (facts, concepts, relations, structure, method). The use of ESD can be measured by means of computer log-files, that indicate what ESD are used.

2.2 Research hypotheses

There are many possibilities of adapting ILE to learner characteristics. To ensure the comprehensibility of this report only a subset of possible interactions will be reported on. In this research subjects are not assigned to certain conditions based on individual variables, but are ascribed randomly to research conditions.
Considering the theoretical base and the specific design of our ILE and PLE, the following hypotheses are put forward. The first three hypotheses focus on the effectivity of the learning environments used. The last three hypotheses focus on the interaction between student characteristics, the use of the learning environments and study outcome.

1 Subjects who study in ILE will achieve at least equal study outcomes as subjects who study in PLE or face-to-face lectures.
2 Subjects who use ESD benefit from learning environments where ESD are less discernable. In contrast, subjects who do not use much ESD benefit from learning environments where ESD are discernable. This interaction is expected because low-users may want to skip certain ESD. When ESD are non-discernable this might hinder these learners because they have to read the ESD before they know

[1] The term 'Hypercourseware' is used to envelop software products which provide some combination of hypertext capabilities, e.g., HyperCard™, SuperCard™, LinkWay™, Guide™, Toolbook™ and Plus™.

what ESD it is. On the other hand high-users who always tend to read ESD might find the different lay-out of ESD obstructive.

3 Students who study in ILE achieve higher study outcomes than students using a non-interactive (but still electronic) learning environment.
This expectancy is based on the idea that the action of choosing ESD leads to higher awareness of functions of these ESD.

4 Prior knowledge is positively related to the use of functionalities of the ILE and is a significant interaction variable in the relation between treatment and study outcome.
Previous research has shown the important impact of the variable prior knowledge on the learning process. We expect subjects with high prior knowledge to explore more in ILE, and therefore to make more use of ESD in ILE. We also expect a significant interaction with prior knowledge in the relation between characteristics of the learning material and learning outcome.

5 Good readers use less ESD to support their study activities; reading comprehension is an interaction variable in the relation between treatment and study outcome. No predictions are made about the direction of the interaction.

6 Motivation and ESD-use are interrelated positively; their interaction influences study outcome. No predictions are made about the direction of the interaction.

3 Research set-up

3.1 The interactive learning environment prototype

Basic features

An interactive learning environment is in our conception a demand driven environment in which students are actively involved in selecting, exploring and studying from a knowledge base of learning materials. Students can either browse through the learning materials in a sequential order by using the page-forward or page-backward button, or follow a 'hyperlink' strategy by choosing any part of the learning materials from the *Topic* option in the main menu. The basic content and the embedded support devices can be simultaneously presented in different windows. Choosing a topic (paragraph) returns by default the specific basic content (cf. Figure 2).

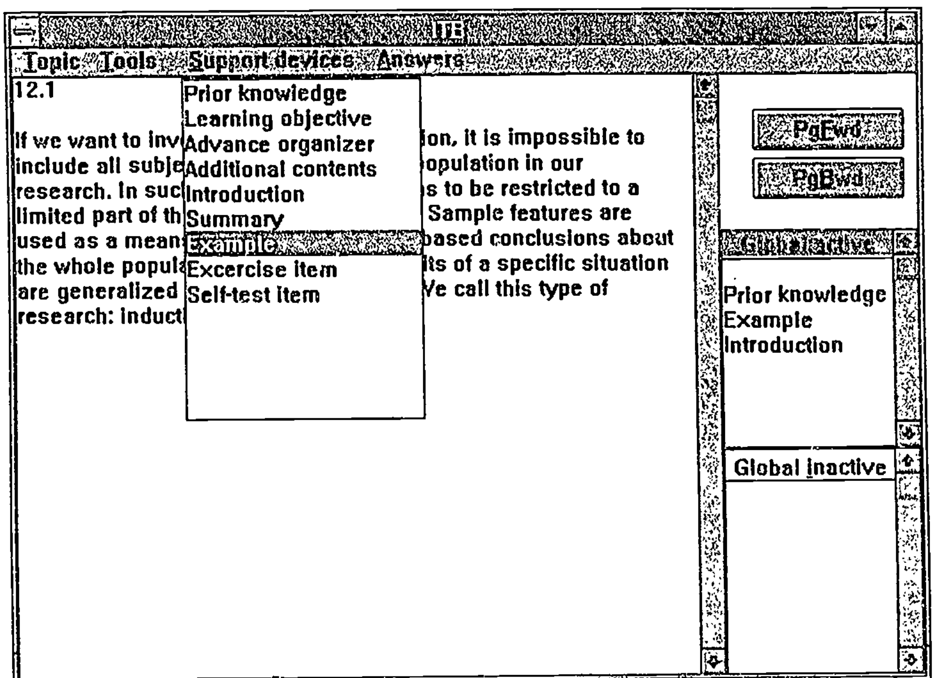

Figure 2. Selection of ESD from the main menu.

In the main menubar students can click on the *ESD* option and 'select' any ESD. This selection represents only a global selection. However, the ESD will be available for further activation at the level of each topic/paragraph. At paragraph-level, the prototype helps to activate or deactivate pre-selected ESD. Activation of ESD is supported from within the *local active* window or from within the *local inactive* window (both in the right part of the screen). If an ESD is selected and active, it is 'embedded' in the basic content, as represented in the central text screen (Figure 3).

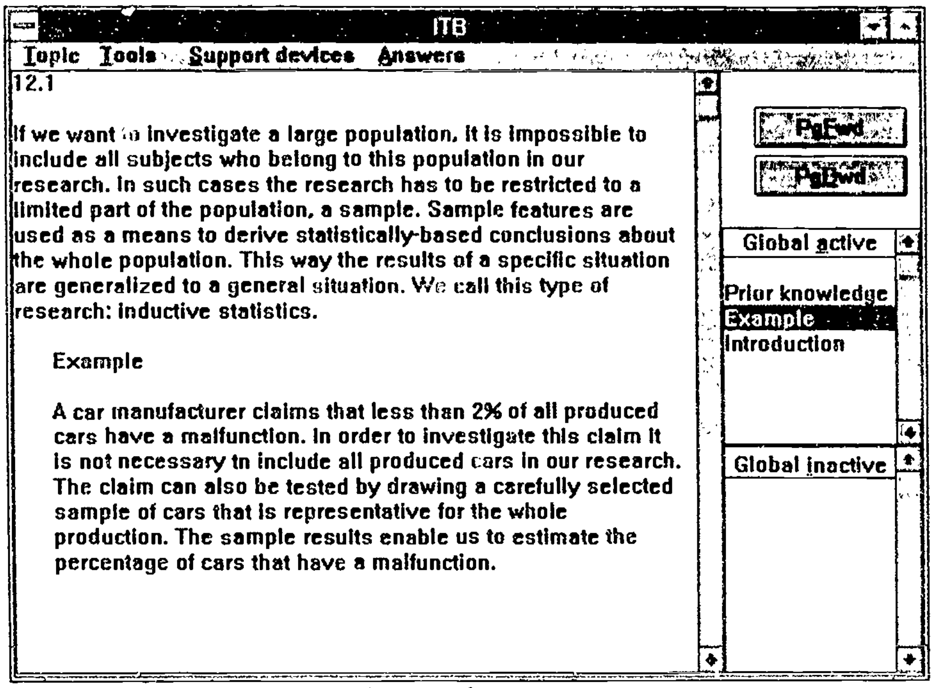

Figure 3. Integration of ESD in basic content.

Figure 3 clearly shows that ESD are separated from the basic content. Tables and illustrations can be accessed by clicking hot-words.

The *Tools* option in the main menubar gives access to a *history* provision and the *glossary*. Activation of the *history*-tool lists all paragraphs that already have been looked at during a session. Activation of the second tool, the *glossary*, results in the presentation of an alphabetic list including all main concepts of the statistics domain covered in the set of learning materials. Selecting one of the concepts leads to the presentation of a short definition of that topic. Furthermore, the glossary can - on demand - provide the student with an example and if needed, the student can add an annotation to the definition. This annotation is stored separately for each individual student.

The fourth option in the main menubar, *Answers*, gives access to the correct answers and solutions for the tasks and exercises included as ESD in the learning materials.

For investigation purposes, all student interactions with the system are stored in a log-file. ESD-interactions, use of hyperlink features and glossary consultation are considered as measures for active involvement of a student. Note that discernability of ESD is one of the conditions and cannot be manipulated by students in this experiment.

3.2 Versions of ILE

The distinction between basic content and ESD is a basic feature in our ILE. Considering the degree of discernability of the ESD and the degree of interactivity in selecting and/or activating the ESD, three versions of interactive learning environments have been elaborated.

In a first version, the interaction possibilities with the ESD have been blocked. In this way the interactive learning environment is reduced to a simple, straightforward electronic textbook.

In two other versions, students are presented with a different way of embedding the support devices; the ESD are either discernable or not discernable in the context of the basic content. In the former setting, the ESD and basic content are clearly separated, and each ESD is preceded by a header, indicating

the type of ESD which is presented (cf. the example in Figure 3). In the latter setting the ESD and basic content are completely integrated.
The versions of ILE are prototypes. Prototyping is seen as an essential part of courseware development to enhance the quality (cf. Gray and Black, 1994).

3.3 Printed learning materials

Basic features
As stated earlier the Ou still mainly supports independent learning with printed learning materials. A variety of models has been elaborated; e.g., textbook-working book model, learning unit model, case model, etc. The printed learning environments have in common that the basic content is enhanced with a rich set of ESD.

3.4 Versions of printed learning environments

Comparable to the ILE the distinction between basic content and embedded support devices is a basic one. But the degree of discernability of the embedded support devices can vary. For research purposes, two different versions of printed learning materials have been elaborated. In a first version, the ESD are discernable and are preceded by a header. In a second version, all ESD are completely integrated into the basic content and, as a consequence, no longer discernable.

3.5 Traditional face-to-face lectures

The traditional face-to-face lectures are held for large groups of students, with one professor giving lectures on inferential statistics. This group is interpreted as the control group.

3.6 Methodology

The entire first-year student population, studying 'Psychology and Educational Sciences' at the University of Gent, Belgium (n=502) participated in the study. Students were assigned, randomly, to either one of five experimental groups or to the control group (Table 1). Students in the control group were not subjected to any particular treatment. They followed the regular face-to-face lectures, given by their usual professor. In the results section, only the scores and behaviour of students who participated in all experimental sessions or corresponding lectures will be used for statistical analysis. Moreover, students with a higher educational background (n=31) and students who take the course for the second time (n=79) are excluded from statistical analysis.

Table 1: First-year student population at the University of Gent, Faculty of Psychology and Educational Sciences, Course Statistics I (N=502).

	Experimental groups		**Control group**
	Discernable ESD	**Non-discernable ESD**	
ILE	I (n=40)	IIIa (n=20) IIIb (n=20) non-interactive	V (n=342)
PLE	II (n=40)	IV (n=40)	

Considering the theoretical model for this research, a large number of processes and variables have to be dealt with. In part, certain variables can be controlled for by the specific research design (e.g., random selection of students). Some variables have to be explicitly measured or evaluated by making use of the following instruments:

- a reading comprehension test;

- a prior-knowledge-state test used as a pre-test;
- a subject-oriented mastery test used as a post-test and to determine study outcome;
- a three-part questionnaire:
  * part A includes questions about motivation, age, study habits, educational level and gender;
  * part B asks students to judge the degree of accessibility of the learning materials studied;
  * part C puts forward questions about the use and appreciation of each specific embedded support device.
- an attitude measuring scale in relation to learning with computers;

The research procedure is reported in chronological order:

* Administration of the reading comprehension test, prior knowledge state test and Ou-questionnaire part A
* Assignment of students to experimental or control groups. We controlled for differences in prior knowledge.
* Introduction session to learn how to use the ILE
* Taking the course: the alternative approaches
  - Students in the experimental conditions study during three sessions of two hours each with the specific learning environment. After each session they fill in the Ou-questionnaire, part C.
  - Students in the control condition follow the regular lecture-format. Three lectures were given, each lecture focusing on one of the selected chapters on inferential statistics.
* Administration of the subject-oriented mastery test and Ou-questionnaire part B
  Test administration was organised one week *after* the research sessions were finished.
* The final examination
  At the end of the academic year, students have to take a statistics examination as a part of their final assessment of the first year. The results of this regular examinations are considered as long-term study outcome effects and can be compared partly with the scores of the subject-mastery test.

4 Results

Table 2 presents an overview of mean post-test scores and of the students in the different treatment conditions. In the further analyses the following techniques have been applied: regression analysis, ANOVA, MANOVA and Profile analysis. The latter technique is an extension of MANOVA and is especially useful to unravel interaction effects between multi-level independent variables, treatment conditions and dependent variables.

Table 2: Post test scores as a function of experimental condition

condition	I electronic, discernable, interactive	II paper discernable	IIIa electronic, non-discernable, interactive	IIIb electronic, non-discernable non-interactive	IV paper, non-discernable	V lectures
mean score	7.58	7.69	7.65	6.38	8.19	7.97
N	24	29	20	8	26	132

4.1 Use of ESD in ILE

Analysing the data of the on-line registration of student-activities in the ILE shows that about 47% of all ESD are actually used by the students.

4.2 Comparing the different conditions

Analysis of variance (ANOVA) is used to judge the significance of differences in mean post-test scores (Table 2). No significant differences are found between the research conditions. Consequently, none of the conditions leads to better study outcomes than any other condition $F(5,233) = .541$ ($p = .745$).

A similar analysis is used to test whether a difference appears later on. Analysis of variance reveals no significant effects of experimental condition on mean final examination scores.

4.3 Delivery mode and study outcome

In this analysis a comparison is made between the groups I, IIIa and IIIb (ILE) and the groups II and IV (PLE). This comparison, based on ANOVA, does not show significant differences in mean study outcome $F(1,50) = 1.441$ ($p = .236$).

4.4 Interactivity mode and study outcome

In this ANOVA, the results of group I and IIIa are combined (fully interactive conditions) and compared with the results of group IIIb where the interactive selection of ESD was obstructed. Analysis of variance reveals no significant main effects nor interactions of the independent variables on study outcome ($F(1,26) = 1.048$ ($p = .315$). However, multiple classification analysis (MCA) produces that the mean deviations from the grand mean of study outcome are negative in case ESD cannot be manipulated (selected). The groups that could work with a full interactive version of the prototype achieve predominantly higher study outcomes than the grand mean.

4.5 Discernable versus non-discernable ESD

For this analysis the mean scores of group I & II are compared with the mean post-test scores of group IIIa, and IV. The purpose of this analysis is to investigate whether discernability of ESD is beneficial. The main effect of the analysis of variance reveals no significant result. Interactive condition: $F(1,42) = .007$ ($p = .935$); paper condition: $F(1,53) = .499$ ($p = .183$).

Multivariate analysis of variance reveals no significant main effects of discernability, nor use of several types of ESD on study outcome. However, if the two-way interactions are taken into consideration, the analysis uncovers a significant interaction between discernability and the use of processing ESD ($F(1,42) = 5.66$, $p < .05$) on study outcome. Additionally we find a trend interaction between discernability and use of testing ESD ($F(1,41) = 3.67$, $p = .06$). The features of both interactions are analogous: students who use much processing and testing ESD benefit from a condition (treatment) in which ESD are non-discernable, i.e., integrated into the basic content. In contrast, low ESD-users seem to benefit from a condition in which ESD can be clearly identified.

4.6 Effects of treatment conditions on the use of ESD

Multivariate analyses of variance reveals no significant main effects nor interactions of discernability and interactivity mode on the use of ESD. However, the use of ESD is significantly affected by delivery mode. In order to analyze the effects of delivery mode on ESD-use we use the data that were collected by means of questionnaire part C. Again, the ESD are clustered according to the dimensions orienting, processing and testing and entered in a profile analysis procedure (parallelism test). The analysis produces a significant interaction between delivery mode and ESD-use, showing that the computer groups use more testing ESD, whereas the paper groups use more orienting and processing ESD (Wilks' $\lambda = .74$, $p < .001$).

4.7 The impact of prior knowledge

In order to determine the effects of the prior knowledge state (PKS) on the use of ESD, we apply a multivariate analysis of variance in which PKS is defined as an independent variable and the use of orienting, processing and testing ESD as dependent variables. The analysis reveals a significant interaction between PKS and ESD-use in this sense that PKS has an enhancing effect on ESD-use. Moreover, this effect is significantly more pronounced for processing ESD and testing ESD (Wilks' $\lambda = .88$, $p < .05$). The interaction effect is supported by univariate F-tests, which reveal that PKS has a significant, positive impact on the use of processing ESD ($F(1,50) = 6.12$, $p < .05$) and the use of testing ESD ($F(1,50) = 3.99$, $p = .05$), but not on using orienting ESD.

In an additional analysis we tried to unravel the prior knowledge effects. To this end, the data representing the two prior knowledge dimensions (behaviour and knowledge) were entered in stepwise multiple regression analyses as independent variables. As dependent variables we entered the three types of ESD: orienting, processing and testing ESD. The results (table 3) show that the use of processing and testing ESD can be predicted from prior knowledge scores on the know and relation parameters (positively related to the use of processing ESD), and scores on the insight and structure parameters (positively related to the use of testing ESD).

Table 3: Stepwise multiple regressions equations (PIN = .05) for use of ESD types as a function of prior knowledge profile

dependent variable	predicting variables	equation
orienting ESD	behavioural parameters: know, insight, apply	none of the variables reached PIN = .05 limit
orienting ESD	knowledge parameters: concept, relation, structure, method	none of the variables reached PIN = .05 limit
processing ESD	behavioural parameters: know, insight, apply	procesd = .09 + .14 * know
processing ESD	knowledge parameters: concept, relation, structure, method	procesd = .11 + .10 * relation
testing ESD	behavioural parameters: know, insight, apply	testesd = .17 + .16 * insight
testing ESD	knowledge parameters: concept, relation, structure, method	testesd = .16 + .17 * structure

Does the impact of PKS on ESD-use also influence study outcome, depending on the learning environment used? To answer this question, we compare the study o utcome of students as a function of their PKS and type of learning environment. We discover that high PKS-students achieve higher study outcomes than low PKS-students. This effect is most pronounced in the condition in which ESD are integrated into the basic content ($F(1,43) = 4.33$, $p < .05$).

4.8 The impact of motivation

Profile analysis (parallelism test) of the effect of motivation on the use of the three ESD-types uncovers no significant main effect nor any significant interaction. In contrast, the analyses on the effects of attitude towards learning with computers revealed a significant main effect (Wilks' $\lambda = .89$, $p < .05$), reflecting that a positive attitude leads to an increased ESD-use. This effect was significantly more important for the use of testing ESD (Wilks' $\lambda = .91$, $p < .05$).

Analysis of variance revealed no significant main effects nor interactions between attitude towards learning with computers and discernability mode or interactivity mode. The picture that arises if we concentrate on delivery mode is completely different. The results indicate a classical disordinal interaction which is supported by a significant interaction effect between attitude and delivery mode on study outcome ($F(1,93) = 4.32$, $p < .05$). The interaction implies that the choice of a certain delivery mode depends on a student's attitude towards learning with computers. Students who like learning with computers will achieve better study outcomes in a computer condition, but will achieve worse study outcomes if they have to study from printed learning materials.

4.9 The impact of reading comprehension

The results of the reading comprehension test are entered in regression analyses in order to investigate the predictive power towards the use of ESD. None of the analyses reveal significant effects, which means that reading comprehension level and use of ESD are seemingly unrelated. However, if we take Pearson's r correlations into account, these appear to be slightly negative for all types of ESD. This might indicate a weak tendency that a low reading comprehension level is compensated by using more ESD (reading comprehension and use of orienting ESD: $r = -.039$; $p = .765$; reading comprehension and use of processing ESD: $r = -.025$; $p = .841$; reading comprehension and use of testing ESD: $r = -.030$; $p = .551$).

5 Discussion

The discussion and interpretation of the results, will be structured according to the hypotheses.

Hypothesis 1: Students studying in ILE will achieve a comparable study outcome as students studying in alternative learning environments.

Since the results reveal no significant differences in study outcome when comparing students in the treatment conditions, the hypothesis can be accepted.

For more information on the comparison of independent learning groups with the control group who received traditional learning approaches we refer to Dekeyser, Goeminne, Schuyten, Martens, Portier, Valcke & Van Buuren (in prep.). Our results confirm earlier findings of Weges and Ellerman (1994), and Portier and Van Buuren (in press). Both studies evidenced that students who study in a computer-based learning environment are able to pass the final examinations, achieve equal results if compared to students in a traditional educational setting. Doubts towards computer-based delivery as for instance expressed by Kozma (1991) can be rejected. Students are able to acquire the necessary knowledge and skills by reading and learning from a computer display.

Hypothesis 2: Subjects who use ESD benefit (higher study outcome) from the undiscernible condition. In contrast, subjects who do not use ESD, benefit from learning materials where ESD are clearly discernable.

The results show a significant interaction: students who use many processing and testing ESD benefit from a condition in which ESD are integrated into the basic content of the learning materials. On the other hand, students who use only few ESD benefit from learning materials in which ESD are clearly discernable. The interaction was only significant for students studying in the ILE. As a result, this hypothesis can only partly be accepted.

The results are in line with results reported by Portier and Van Buuren (in press): some students explicitly indicated that they would prefer a discernable delivery of ESD, whereas others seemed to prefer a completely integrated delivery.

Hypothesis 3: Students who study in an interactive learning environment achieve a higher study outcome than students using a non-interactive learning environment.

Considering the results, this hypothesis has to be rejected. Interactivity is one of the basic functionalities of the prototype of the interactive learning environment. At the theoretical level, interactivity was implemented in our approach because of a constructivist perspective on learning (e.g., Martin, 1984), which states that the acquisition of new knowledge schemes benefits from an active self-directed learning process.

A possible explanation for the non-significant differences can be found in the relatively small number of students who studied in the non-interactive learning environment setting.

Hypothesis 4: The prior knowledge state of a student is positively related to the active use of the interactive learning environment, and is an interaction variable in the relation between treatment and study outcome.

The analyses reveal that PKS is positively related to ESD-use. Moreover, it appears that this effect is especially present for processing and testing ESD. At a detailed level it is found that the use of processing ESD can be predicted from particular subscores of the PKS (*know* and *relation*). In parallel, the use of testing ESD is positively related to subscores on the *insight* and *structure* parameter. As a conclusion, we can state that the first part of the hypothesis can be accepted.

If we research the interaction of prior knowledge between ESD-use and study outcome, we perceive that the effect is significantly more pronounced in a condition where ESD are not discernable, i.e. integrated into the basic content. Also the second part of the hypothesis can be accepted. This specific interaction can be explained as follows: Students with a high level of prior knowledge can compensate for the lack of structure in the low discernability condition (cf. Matthews, 1982), since they can rely on knowledge structures already available. Students with a lower level of prior knowledge do not have this knowledge, which leads to a negative impact on their study outcome if the task environment is also unstructured.

Hypothesis 5: Good readers need less ESD to support their study activities. Reading comprehension is an interaction variable in the relation between treatment and study outcomes.

Considering the non-significant analysis results, the first part of this hypothesis is rejected.

In our theoretical model, the reading comprehension process is considered to be closely related to the learning process. Oostendorp and Peeck (1991) argue that reading does not always imply a learning intention directed at changing an existing cognitive structure. The difference between reading and learning is associated with the intentionality of the reading process. Our reading comprehension test did focus on *comprehending* text fragments. However, the test did not focus on *learning* these text fragments. This might explain the weak relationship between reading comprehension level and the use of supportive elements in the learning materials.

The analysis results also do not support the second part of the hypothesis, since there are no significant interactions between reading comprehension level and any of the experimental conditions. The discussion about the 'intentionality' of the reading process is also relevant here. In addition, we may question what the relevance is of reading comprehension in the domain of learning statistics. It is possible that reading comprehension is clearly related to understanding and learning predominantly textual learning material, but a considerable part of a statistics course includes the application of methods (formulas), making exercises or solving problems.

Hypothesis 6: Motivation and ESD-use are positively interrelated; their interaction influences study outcome.

Our measures of motivation do not reveal an influence of motivation on the use of ESD-types. This is in contrast with our model, since we expected an influence of motivation on the use of ESD.

The concept of attitude is related to the concept motivation. A questionnaire on attitude towards computers shows that students' attitude towards learning with computers appears to be positively related to ESD-use. The latter effect is significantly more pronounced for testing ESD. Post-hoc analysis showed a significant positive correlation between attitude and motivation.

As to the interaction effect of motivation, influencing the use of the learning environment and as such influences post test scores, no significant interaction effects have been found. But if we introduce again the relation between 'motivation' and 'attitude towards learning with computers', a different picture appears. In the interactive learning environment, a students' attitude towards learning with computers is a significant, predictive variable for the variable study outcome.

In summary, hypothesis 6 is to be rejected but via the relation with attitude towards computers there is a relevant influence of a non-cognitive variable.

5.1 Conclusions

Regarding the main aims of the present study, the research results show the relative effectivity of independent learning materials and of ILE.

The ILE are not less effective than printed learning environments or face-to-face lectures. For efficiency reasons face-to-face lectures might be replaced by self study conditions. It must be noted however that the conditions in which we used self study materials where not completely self study conditions, because the materials could not be studied at home.

The extra possibilities that ILE offer did not result in better study outcomes than the other self study conditions, based on printed learning materials. The latter are much easier to make. This means that the present study did not reveal extra benefits from interactive learning materials. Some possible explanations are:

- In every condition students knew they had to achieve the same study results. This might imply that less optimal conditions are compensated for by for instance studying with more effort. This is a general problem in this type of research (Martens et al, 1995,a).
- The ILE used in this experiment was still based on text and support devices intended for printed self study materials.

Although comparison of the different types of ILE does not result in significant differences in learning outcome, this study shows that individual student characteristics play a role in making use of the learning environment and as such influence study outcome. Depending on the degree to which particular settings of the interactive learning environment (discernability, interactivity, ESD-use) are in line with student characteristics, the effectivity of ILE is different.

Extrapolating these findings to the future design of ILE, this implies that students might be advised -automatically- about a preferred combination of settings (e.g., to select or deselect ESD, to make them discernabie or not, to get a printed version next to the interactive versions). However control to adapt the learning environment to individual needs should always be in the hands of the individual student. In future prototypes of ILE we will therefore try to improve the adaptivity to student characteristics and students' preferences. This will also imply the development of new, interactive ESD. In this way, we hope to develop and implement an interactive learning environment that optimizes the task environment to the needs of the individual student.

6 References

Ausubel, D.P. (1968). *Educational Psychology: a cognitive view.* New York: Holt, Rinehart and Winston.

Ames, R.E. & Ames, C. (1984). *Motivation in education. Volume 1, student motivation.* San Diego: Academic Press inc.

De Diana, I.P.F., & Van der Heiden, G. (1994). Electronic study books and learning style. *Journal of computer assisted learning, 10*, 113-124.

Dochy, F.J.R.C. (1992). *Assessment of prior knowledge as a determinant for future learning.* Utrecht/London: LEMMA, Jessica Kingsley.

Dochy, J.R.C., & Alexander, P.A. (1995). Mapping prior knowledge. A framework for discussion among researchers. *European journal of psychology of education, vol xx,* 1, 1995.

Elshout-Mohr, M. (1991).Terugkoppeling in het kader van zelfinstructie [Feedback in the contex of self-instruction]. *Pedagogische Studiën, 68,* 7, 305-314.

Esichaikul, V., Smith, R.D., & Madey, R. (1994). The impact of learning style on problem solving performance in a Hypertext environment. *Hypermedia, 6(2),* 101-110.

Gray, D.E.,& Black, T.R. (1994). Prototyping of computer-based training materials. *Computers and education, 22,* 251-256.

Jones, M. (1992). Introduction on Adaptive Learning Environments. In M. Jones & P.H. Winne (Eds.). *Adaptive Learning Environments* (pp.3-10). Berlin: Springer Verlag.

Lockwood, F. (1992). *Activities in self-instructional texts.* London, Philadelphia: Kogan Page.

Kozma, R.B. (1991). Learning with media. *Review of Educational Research,* 61, 179-211.

Larkin, J.H. & Chabay, R.W. (1992). *Computer-Assisted Instruction and Intelligent Tutoring Systems: Shared goals and complementary issues.* Hillsdale: Lawrence Erlbaum.

Lawler, R.W. Learning environments: Now, Then and Someday. In R.W Lawler & M. Yazdani (1987). *Artificial Intelligence and Education* (pp.1-26). Norwood: Ablex (1987).

Martens, R.L., Poelmans, P.H.A.G., Daal, M.M., & Valcke, M.M.A. (1993). *Varying embedded support devices in a course: what is the effect?* OTIC Research Report 44. Heerlen: OTIC, Open university.

Martens, R.L., & Valcke, M.M.A. (1993). Validation of a theory about the functions and effects of embedded support devices in written study materials. In Valcke, M. & Lockwood, F. (Ed.), *Research in relation to new developments in distance education materials.* (pp. 66-84). Heerlen: Open university.

Martens, R.L., Portier, S.J., Valcke, M.M.A., Van Buuren, J.A., Dekeyser, H., Goeminne, K., &

Schuyten, G. (1995, A). *The use of embedded support devices in ILE: The impact of student characteristics; Theoretical base and research setting.* OTIC Document 33. Heerlen: OTIC, Open university.

Martens, R.L., Portier, S.J., Valcke, M.M.A., Van Buuren, J.A., Dekeyser, H., Goeminne, K., & Schuyten, G. (1995, B). *The use of embedded support devices in ILE: The impact of student characteristics; Research results.* OTIC Document. Heerlen: OTIC, Open university.

Martens, R., Poelmans, P., Daal, M., Van Staa, A., & Van Meurs, C. (1993). *Leren in verschillende leerstofgebieden: consequenties van de didactische uitwerking* [Learning in various content domains: consequences of the didactical elaboration]. Unpublished manuscript.

Martens, R.L., Poelmans, P.H.A.G., Daal, M.M., & Valcke, M.M.A. (1993). *Varying embedded support devices in a course: what is the effect?* OTIC Research Report 44. Heerlen: OTIC, Open university.

Martens, R.L., Poelmans, P.H.A.G., Daal, M.M., Valcke, M.M.A., & Stolk, J. (1994). *Eye movement registration during studying: an explorative study of the use of embedded support devices.* OTIC Research Report 64. Heerlen: OTIC, Open university.

Martin,.J. (1984). Toward a cognitive schemata theory of self-instruction. *Instructional science,* 13, 159-180.

Matthews, S.R. (1982). The impact of prior knowledge on accesibility and availability on information from prose. In A. Flammer & W. Kintsch (Eds.), *Discourse processing.* Amsterdam: North Holland.

Mayer, R.E. (1979). Twenty years of research on advance organizers. *Instructional Science,* 8, 133-167.

Mayes, T., Kibby, M. & Anderson, T. (1990). Learning about learning from Hypertext. In D.H. Jonassen & H. Mandl (Eds.), *Designing Hypermedia for Learning.* Berlin: Springer-Verlag (pp. 227-250)..

McCalla, G.I. (1992). The search for adaptability, flexibility, adn individualization: approaches to curriculum in intelligent tutoring systems. In M. Jones & P.H. Winne (Eds.), *Adaptive Learning Environments* (pp.91-121). Berlin: Springer Verlag.

Portier, S.J., & Van Buuren, J.A. (in press) .An interactive learning environment to study statistics: Effects of prior knowledge on the use of embedded support devices. *European Journal for the Psychology of Education.*

Segers, M.S.R. (1993). *Kwaliteitsbewaking in het hoger onderwijs.* [Controlling quality in higher education]. Utrecht: Lemma BV.

Snow, R.E. & Swanson, J. (1992). Instructional psychology: aptitude, adaption, and assessment. *Annual Review of Psychology, 43,* 583-626.

Sternberg, R.J. (1986).*What is intelligence? Contemporary viewpoints on its nature and definition.* Norwood, New Jersey: ABLEX.

Thompson, A.D., Simonson, M.R., & Hargrave, C.P. (1992).*Educational technology: A review of the research*. Washington: AECT.

Valcke, M.M.A., Martens, R.L., Poelmans, P.H.A.G, & Daal, M.M. (199:). The actual use of embedded support devices in independent learning materials by students in a distance education setting. *Distance education*, 14, 55-84.

Van Driel, J.H., & van den Berg, G.C. (1994). Hoe kan een systeem van kwaliteitszorg docenten stimuleren tot onderwijsverbetering?. [How can a system of quality control promote teachers' improvements of education?]. *Tijdschrift voor Hoger Onderwijs, 12,* 238-249.

Van Hout Wolters, B.H.A.M., & Willems, J.M.H.M. (1991). Zelfinstructie : Mogelijkheden en beperktheden [Self-instruction: Possibilities and restrictions]. *Pedagogische Studiën*, 68, 7, 284-294.

Van, Oostendorp, H., & Peeck, J. (1991). Leren uit teksten. In Thomassen, A.J.W.M., Noordman, L.G.M., & Eling, P.A.T.M. *Lezen en begrijpen. De psychologie van het leesproces* [Learning and understanding: the psychology of reading]. Amsterdam/Lisse: Swets & Zeitlinger.

Waller, R.H.W. (1979). Typographic access structures for educational texts. In Kolers, P.A., Wrolstad, M.E. & Bouma, H. (Eds.), *Processing of Visible Language*. New York.

Weges, H.G. & Ellermann, H.H. (1994). Flexibilisering met behulp van interactive leeromgevingen: nu en in de toekomst [flexibilisation by means of interactive learning environments: now and in the future]. *Tijdschrift voor hoger onderwijs, 12,* 250-268.