Adaptive Hypermedia and Cognitive Styles: Can Performance Be Influenced?

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Abstract. The importance of cognitive style on student's performance in learning environments stresses the need for careful design and development of hypermedia based learning materials. Our research complies and synthesizes findings in current literature in an effort to develop an Adaptive Educational System based on Cognitive Styles (AES-CS), a prototype system that includes accommodations for cognitive styles in order to improve students' interactions and learning outcomes. In order to evaluate the effectiveness of the prototype system an empirical study was conducted and this paper presents the results of this evaluation.

1 Introduction

The advent of the World Wide Web has facilitated the use of hypermedia resources in teaching and learning. Currently, there is a large number of hypermedia environments covering a wide range of topics. Hypermedia environment is considered to be a flexible instructional environment in which all the learning needs can be addressed [1]. Many researchers have been working to construct sophisticated hypermedia systems, which can identify the user's interests, preferences and needs and give some appropriate advice to the user throughout the learning process. Adaptive Hypermedia was introduced as one possible solution. Adaptive Hypermedia Systems (AHS) combine hypermedia systems with Intelligent Tutoring Systems to adapt web-based educational material to particular users. AHS permit the tailoring of instruction to meet individual students needs.

Adaptive Hypermedia (AH) is an alternative to "one-type-suits-all" approach. AH build a user model of the goals, preferences and knowledge of the individual user and use this model to adapt the content of pages and the links between them to the needs of that user. Since the user's goals, preferences and needs may change over time, AH observe these changes in order to update the user's model [2]. There are two major technologies in adaptive hypermedia: a) adaptation of the content of pages, referred as adaptive presentation, b) the adaptation of hypertext links which mainly affects navigation within a hypertext system, referred as adaptive navigation.

Adaptive Educational Systems (AES) can be developed to accommodate various learner needs; is the ideal way to accommodate a variety of individual differences, including cognitive style. The way individual process learning cues is referred as cognitive style. The role of cognitive style is critically important associated with student success in any learning situation [7, 8, 18]. There are many different defini-

tions of cognitive styles as different researchers emphasize on different aspects [10]. Witkin [14, 15] has done extensive work in this area and has defined two basic styles, field dependent (FD) and field independent (FI). Field dependence/independence (FD/FI) is probably the most well known division of cognitive styles [15].

According to Witkin, field dependence-independence has important implications for an individual's cognitive behavior and for his/her interpersonal behavior. While most learners fall on a continuum between these two cognitive processing approaches, each style is defined by certain characteristics. Specifically, field independent people tend to be more autonomous in relation to the development of cognitive restructuring skills and less autonomous in relation to the development of interpersonal skills. Conversely, field dependent people tend to be more autonomous in relation to the development of high interpersonal skills and less autonomous in relation to the development of cognitive restructuring skills.

Furthermore, FD/FI dimension refers to a tendency to approach the environment in an analytical, as opposed to global, way. Field independent (FI) learners generally are analytical in their approach while Field Dependent (FD) learners are more global in their perceptions. Furthermore, FD learners have difficulty separating the part from the complex organization of the whole. In other words, FD individuals see things in the entire perceptual field (the forest than the trees). Additionally, FI individuals tend to be intrinsically motivated and enjoy individualized learning, while FD ones tend to be extrinsically motivated and enjoy cooperative learning. Specifically, FD individuals are more likely to require externally defined goals and reinforcements while the FI ones tend to develop self-defined goals and reinforcements [15].

1.1 Significance of Cognitive Style

Many experimental studies have showed the impact of field dependence/independence on the learning process and academic achievement. Studies have identified a number of relationships between FD/FI cognitive style and learning, including the ability to learn from social environments, types of educational reinforcement needed to enhance learning and amount of structure preferred in an educational environment [11].

Research by Wey and Waugh [17] indicates that FD people may benefit more from text with graphic format. Graphics will provide external cues for FD people and result in better performance. Another study was conducted by Jonassen and Wang [5]. The results implied that students with different cognitive styles choose different learning strategies for learning. Liu and Reed [7] studied the relationship between cognitive styles and learning strategies in a hypermedia-based second language-learning environment. They found that FD and FI learners responded differently to program features that emphasized respectively the holistic and componential representations of information. They concluded that hypermedia learners with different cognitive styles performed equally well in assessment but employed different learning strategies. Different learning strategies refer to the choice of different media, different tools and different learning aids.

The amount of learner control seems to be a central variable when integrating adaptive methods in educational settings. There are several arguments in the literature for and against learner control. On the one hand, learners' motivation is increased

when they control the navigation of a hypermedia environment. On the other hand, research seems to indicate that the amount of learner control depends on the pre-skills and the knowledge state of a learner [13]. Furthermore, many studies have demonstrated student preference and improved performance using a linear structure. With regards to cognitive styles, there is evidence that FD individuals perform better using program control while FI ones prefer more learner control [18].

Several problems of learning in a hypermedia environment arise from the structure of the environment itself. In an ideal web site, the structure is evident to the user and the information is organized coherently and meaningfully. Navigational tools are essential in order to assist learners to organize the structure of the web site as well as the connections of the various components. A coherent resource collection will allow the user to construct an accurate mental model of the topic. Research has indicated that FD learners are less likely to impose a meaningful organization on a field that lacks structure and are less able to learn conceptual material when cues are not available [15]. Furthermore, Jonassen and Wang [5] argue that the FI learners generally prefer to impose their own structure on information rather than accommodate the structure that is implicit in the learning materials.

The studies above illustrate some aspects of the interaction between cognitive styles and learning strategies. These studies demonstrate the importance of cognitive style on student's performance in hypermedia learning environments. Designs of web-based courseware that includes accommodations for cognitive style can only result in improved student interactions and outcomes.

2 Overview of Study

Numerous AES have been implemented over the last fifteen years. INSPIRE [9] and CS383 [3] are good examples of AES with regards to learning style. Although, cognitive styles are one of the several important factors to be considered from designers and instructors of hypermedia-based courseware, little research has been done regarding the adaptation of hypermedia system to students' cognitive styles [6] and this is the focus of our research.

The purpose of this study was to investigate the hypothesis that the adaptivity based on student's cognitive style could be beneficial for the observed learning outcomes. As a case study a Higher Education module was developed, called AES-CS (Adaptive Educational System based on Cognitive Styles), to support the course "Multimedia Technology Systems" which is typically offered to fourth year undergraduate students in Computer Science Department at the Aristotle University of Thessaloniki, Greece. The current interface of AES-CS and its functionalities are the result of several revisions based on the analysis of the data collected during the formative evaluation of the system [12]. However, in order to evaluate the educational effectiveness of system's adaptation, an empirical study was conducted and this paper presents the results of the summative evaluation of the system.

3 Method

3.1 Subjects

Fourth year undergraduate students studying the course "Multimedia Technology Systems" volunteered to take part in the study. Students were domain novices and they never before used systematically hypermedia based instructional environment for any other course. They were allocated in two groups: experimental (36 students) and control (30 students).

3.2 Learning Materials

The first four lessons on Multimedia Technology Systems were used as the example learning material in this phase. These lessons cover issues on digital information, text, digital image and digital sound respectively. The first lesson introduces basic digitizing concepts such as sampling, sampling rate, quantization, and compression. The second lesson covers issues on text: digitizing, appearance and standard format. The third lesson provides issues on digital images such as: bitmap and vector images, resolution, color depth, color model, size, image compression standards and software. The last lesson covers issues on digital sound such as: wave and midi format, sampling size, sampling rate, audio compression standards and software.

3.3 Instruments

Four testing instruments were used in this study. The first was the GEFT [16], which was used to determine the cognitive style of the participants. The second was a pre-test with ten (10) open-ended items, which was designed to determine subject's prior knowledge on the domain. The third one was an immediate post-test, which consisted of a performance test with the same items as the pre-test to verify any increase in understanding at the end of the instruction. The fourth was an attitude and acceptance questionnaire for the experimental group that included items relating to the completeness and ease of use of the system, and also items on subject's satisfaction and willingness to use the system.

3.4 Procedure

The course "Multimedia Technology Systems" is offered to fourth year undergraduate students. Typically the students follow the lectures and they study through a hypermedia-based environment. The experiment took place over a four-week period and during that period AES-CS was an integral part of the course together with the lectures and the hypermedia-based environment. The procedure was completed in four stages for both experimental and control groups. In the first stage all the subjects were informed that they will participate in an experimental process and were asked to complete the GEFT test and the pre-test. At the next stage, the students followed regularly the lectures up to the completion of the first unit, which is constituted by four lessons. The students of the experimental group studied through the adaptive

educational system AES-CS, while the control group studied through the traditional hypermedia based environment.

A user account was created for each student for login purposes into AES-CS. The initial adaptation of the system was according to the cognitive style of the students. Before proceeding with the instruction, the students in the experimental group received a short introduction on how to use the system and were prompted to use its various tools and instructional strategies. All students were advised to work at their own pace without being given any time limit. During the instruction, the students were prompted to use comment logs in order to note specific strengths or weaknesses of the system.

In the third stage, a post-test was used in order to measure the learning gain from the instruction. Moreover, an attitude questionnaire was given to the students of the experimental group aiming to determine their experience in using the system AES-CS. In addition, debriefing sessions were used to assess student's satisfaction on the instructional and interface design of AES-CS. Twenty students from the experimental group were participated in this stage.

4 Data Analysis

4.1 Independent Variables

Cognitive Style. The Group Embedded Figures Test (GEFT) [16] was used to identify the field-dependent and field-independent cognitive style. In this test, subjects perceived the information, which is a series of simple figures, independently from the larger complex figure, in which the simple figures are embedded. The score of the test ranged from 0 to 18, with higher scores indicating a greater degree of field-independence. The students whose GEFT scores were below the mean score (Mean=12,34) were classified as FD, and those whose GEFT scores were above the mean were classified as FI. They were allocated in two groups: experimental (36 students: 15 FD, 21 FI) and control (30 students: 11 FD, 19 FI).

Learning environment. The students of the experimental group studied through the adaptive educational system AES-CS, while the control group studied through the traditional hypermedia based environment. The initial adaptation of the system AES-CS was according to the cognitive style of the students.

4.2 Dependent Variables

Learner achievement. Pre-tests and post-tests having the same content in the form of open-ended items were used to measure the learning gains from the instruction. Ten (10) open-ended items were included in each test. Since each correct answer was graded with two points, the total score for the test was within a range of 0 (10x0, none right answer) to 20 (10x2, ten right answers).

5 Results and Discussion

5.1 Quantitative Data

In this study the factorial design was devised to analyze the independent and interaction effects of two independent variables (environment and cognitive style) on dependent variable (the learning achievement). The factorial designs are a significant development in modern research design because they allow researchers to manipulate, control and analyze two or more variables simultaneously. Another advantage of this research design is that the factorial approach made it possible to investigate interactions, in addition to main effects. An interaction is when the effect of one variable is not the same under all the conditions of the other variable. The study used a 2x2 factorial design with two levels of learning environment (AES-CS & HTML) and two levels of cognitive style (FD &FI).

In order to ensure that both groups had the same prior knowledge on the domain, a test for homogeneity on the data of the pre-test was computed. As expected, the result of the ANOVA presented no significant effects. So, only the post–test was computed into the statistical analysis.

A two-way analysis of variance (ANOVA), with alpha level set at .05, was used to test for main effects and the interaction assumption between learning environment and cognitive style. The dependent variable was learner achievement (post–test). The results revealed a significant main effect for the learning environment [$F_A(1,62)= 6.633$, $p=0.012$]. These findings indicate that students in experimental group performed significantly better than students in control group. Furthermore, these results provide the evidence that the adaptive educational system AES-CS, which was designed to be adapted to individual cognitive styles, can result in improve students interactions and outcomes. On the contrary, the ANOVA results [$F_B(1,62)=1.305$, $p=0.258$] do not show significant main effect of cognitive style for the learner achievement. These results suggest that cognitive style alone did not impact on learner's performance. In addition, the results also indicated no significant interaction between learning environment and cognitive style, [$F_{AxB}(1,62)=1.087$, $p=0.301$].

To supplement the ANOVA analysis, group means and standard deviations of the learner achievement were examined (table 1). Overall, the group mean results show that the students of the experimental group, which studied through the adaptive educational system AES-CS, had higher means. It is important to note that although FD students in experimental group had lower means in the pre-test, finally they had almost the same post-test performance as FI students in experimental group. Moreover, FD students in experimental group had significant higher performance than FD students in control group. So, the results provide evidence that the adaptivity based on student's cognitive style could be beneficial for the observed learning outcomes, especially for FD students.

GROUP	Cognitive Style	Mean	Std. Deviation	N
ADAPT	FD	18.00	2.10	15
	FI	18.05	1.43	21
	Total	18.03	1.72	36
HTML	FD	16.27	2.10	11
	FI	17.32	2.00	19
	Total	16.93	2.07	30

GROUP	Cognitive Style	Mean	Std. Deviation	N
ADAPT	FD	1,87	1,767	15
	FI	3,10	2,644	21
	Total	2,58	2,371	36
HTML	FD	1,55	1,440	11
	FI	3,58	2,652	19
	Total	2,83	2,465	30

Table 1. Performance means on pre and post-test
(Above: Dependent Variable: POST. Below: Dependent Variable: PRE)

5.2 Qualitative Data

The post-test attitude and acceptance questionnaire for the experimental group consisted of two parts. The first part included six (6) items relating to the completeness and ease of use of the courseware. The second part included sixteen (16) items related to subject's satisfaction and willingness to use AES-CS. In addition, twenty students from the experimental group were participated in the debriefing sessions that were used to assess their subjective satisfaction on the instructional and interface design of AES-CS.

An analysis of the data collected showed that overall the subjects were satisfied with the system. In addition, they felt that the system was clear and easy to understand and after working with it they had a better understanding of the area studied. Furthermore, they felt challenged by the instruction and they stated that they wanted to use the system again. However, they also stated that they would prefer to use it as support learning material and not as a substitute to the physical lectures.

Subjects' responses to the open-ended item "Which are the most important features of the application and why?" are in order of preference as follows:

- The self-assessment unit as it could confirm the acquired knowledge,
- The adaptive annotation as it allowed students to know which units had read and in which units they had successfully passed the self-assessment test,
- The concept map and graphics path indicator as they helped them to organize the structure of the knowledge domain affecting both cognitive overhead and coherence,
- The adaptive navigation support was used mainly by FD students and helped them to find the most suitable sequence of knowledge units to learn avoiding disorientation.

The initial adaptation of AES-CS to FD/FI learners was based on research results [5, 8, 18] and theoretical assumptions in FD/FI dimension [4, 15]. An important

evaluation goal was to investigate whether this initial adaptation was the most appropriate for the learners and to verify the design issues that were considered for the development of the system. The majority of the students were satisfied with the initial adaptation based on their cognitive style. However, many students utilized the ability to use the student model or the appropriate interactive buttons in order to change the initial status of the systems' features.

The comments at the debriefing sessions confirm the users' responses to the attitude questionnaire. The majority of the students agreed that they clearly understood how to use the AES-CS. Many user comments focused on the content of the courseware. They stated that the topics were well covered, up-to-date and clearly presented. However, they made suggestions for the improvement of the system. Some of the most significant recommendations are summarized into the following points: a) more in depth information, b) more multimedia elements, and c) additional information regarding wrong answers into the self-assessment unit.

The data obtained via the attitude questionnaire and the debriefing sessions yielded important information. The students agreed that initial adaptation based on their cognitive style was very helpful but they stated that the ability to change the initial stage through the student model or appropriate interactive features was very useful. The students indicated as very important the adaptation granularity of the systems AES-CS. They felt challenged by the system flexibility and they were satisfied with the fact that the system was completely controllable by them.

6 Summary

Adaptive hypermedia systems can be developed to accommodate a variety of individual differences, including cognitive style. Cognitive style is an individual difference that can influence student performance in hypermedia learning environments. Studies have identified a number of relationships between cognitive style and learning. The objective of the overall research was to comply and synthesize findings in current literature in an effort to develop a prototype adaptive educational system based on cognitive styles. In order to evaluate the effectiveness of the prototype system an empirical study was conducted.

The results from the summative evaluation of the prototype system, support the evidence that the adaptivity based on cognitive styles can ensure that all students can learn effectively in a hypermedia environment. Statistical analysis using ANOVA and descriptive statistics indicated that students in experimental group (AES-CS) performed significantly better than students in control group (HTML). These findings indicate that the adaptive educational system AES-CS, which was designed to be adapted to individual cognitive styles, can be an effective tool to support and promote learning. Furthermore, an analysis of the data collected showed that the subjects were satisfied with the initial adaptation based on their cognitive style. In addition, the qualitative data analysis indicated that the adaptation granularity contributed to the overall user satisfaction.

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