Assessing Acceptance of Adaptive Educational Hypermedia Systems: Prior Knowledge vs. Cognitive Styles

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Abstract

Perceived usefulness and ease of use have proved to be key determinants of the acceptance and usage of e-learning systems. On the contrary, little is known about students' perceptions in Adaptive Educational Hypermedia Systems (AEHS). In this paper, the Technology Acceptance Model (TAM) was utilized to investigate university students' attitudes towards AEHSs. The goal of the study was to investigate whether students' perceptions towards AEHS that adapts basing on cognitive styles were comparable to perceptions of students using AEHS that adapts basing on prior knowledge. This is part of a project to determine how prior knowledge and cognitive styles could be combined in AEHS to maximize learning and comprehension of educational materials. To this end, the study presented in this paper developed two AEHSs, one tailored to students' prior knowledge while the other to their cognitive styles with emphasis on Holist-Serialist dimension. Comparative effects of using the two systems employing perceptions and attitudes as a measure were then investigated. In total, 104 students participated in the study, 60 students using the prior knowledge version while 44 participated on the cognitive styles version. The findings indicate that students using the cognitive styles version had more positive attitudes and perceptions towards their version than those who used the prior knowledge version. The implications of these results for the design of effective AEHSs combining prior knowledge and cognitive styles are discussed.

Keywords: *Cognitive Styles, Prior Knowledge, Perceptions, Computer Based Training, Holist, Serialist*.

1. Introduction

An Adaptive Educational Hypermedia System (AEHS) tailors information or content to individual users by employing a user model built based on parameters derived from human factors [2]. These human factors, in an educational context, can range from gender differences [3] through prior knowledge [4, 5] to cognitive styles [6, 7]. Thus, human factors play an important role in the development of AEHSs.

Among the aforementioned human factors, prior knowledge has been widely taken into account in the development of AEHSs. Furthermore, empirical evidence has suggested that matching students' prior knowledge with AEHSs can improve their perceptions of use [8, 9]. However, recent research has focused on cognitive styles as another human factor that can be used to drive adaptation in AEHSs. Some studies have found that adapting to individuals' cognitive styles improves students' perceptions of use [10]. Therefore, there is a need to investigate comparative effectiveness of the two individual differences (prior knowledge and cognitive styles), using perception as measure, prior to formulating ways of incorporating them in a single AEHS in order to maximize learning and comprehension.

Among various dimensions of cognitive styles, Pask's Holist-Serialist [11, 12] is influential to student learning and perceptions of use. Several studies, including [10] found that learning environments matched with the needs of Holists and Serialists could make them have better perceptions of use. Therefore, this study aims to examine the effects of an AEHS that provides an adaptation based on Pask's Holist/Serialist dimension and comparing to the one that provides adaptation based on levels of prior knowledge (i.e. novice and experts). More specifically, this study aims to prototype two AEHSs, one that adapts to a user's cognitive style (Holist-Serialist) and the other that adapt to the levels of prior knowledge. A thorough comparison based on perceptions and attitudes toward the use of the AEHSs is then conducted.

2. Related Research

2.1 Adaptive Educational Hypermedia Systems

Adaptive Educational Hypermedia Systems (AEHSs) have evolved from research in adaptive hypermedia which individualized content basing on certain characteristics of a user, like goals, interests, domain knowledge and other preferences. To achieve this, adaptive hypermedia represents these individual characteristics in a user model for adaptation [13]. The model is then updated as the user's goals and interests change with time or due to some other factors. Educational hypermedia was one of the first application areas of adaptive hypermedia because, in an educational context, users with alternative learning goals and knowledge require essentially different treatment [14]. For example, a student in an AEHS will be given a presentation that is adapted specifically to his or her knowledge of the subject [15] and a suggested set of most relevant links to proceed further [16, 17].

A number of pioneer AEHSs were developed between 1990 and 1996. During that period, most researchers concentrated on building systems that adapt to their students' individual differences [15];[18]. Classical adaptive hypermedia systems, including ELM-ART [19] and InterBook [17]), have been created for educational settings, and tailor information to students' level of prior knowledge. Numerous studies have concluded that adapting to prior knowledge is an important approach to increase the effectiveness and efficiency of learning courses and might even increase users' satisfaction [20].

Table1. Difference learning characteristics of experts and novices (adapted from [25])

Experts	Novices
• Global mental models	• Local mental models
• Directed search	• Undirected search (trial and error
• Deep structures	• Surface structures
• Mental simulation of integrated functions and whole application	• Mental simulation of isolated functions
• Complete analysis deferring details	• Incomplete analysis
• Depth-first strategies	• Breadth-first strategies
• Design whole and add pieces	• Design pieces
• Integrated whole throughout the process	• Failure to integrate pieces into a whole
• Find the best solution	• Find a (any) solution

2.2 Prior Knowledge and AEHSs

Prior knowledge is another important variable that is related to hypermedia learning systems. Previous research indicates that prior knowledge can account for a high level of variance in most learning situations [21]. Individuals' prior knowledge in hypermedia learning includes previous understanding in the content area and levels of system experience appropriate to the program. Learners with high prior knowledge are normally referred to as "experts" while those with low prior knowledge are referred to as "novices". [22] developed a framework to integrate prior knowledge into the design of hypermedia learning systems in which they made a distinction between experts and novices. According to [23], an expert can simply be defined as an individual with formal training and experience in the area under investigation, whereas a novice can be defined as having little or no formal training/experience in the area examined. [24] argue that the contrast between experts and novices lies in the differences in the organisation of their conceptual structures: experts possess a mental representation (i.e. hierarchical structure) of the concepts in the domain, whereas a novice's structure is more chaotic and disordered. The different learning characteristics of experts and novices are summarised in Table 1.

In the past decade, a growing body of research has examined the influence of prior knowledge in hypermedia learning systems. Such research has suggested that different levels of prior knowledge suited to different types of content structure [26] and different navigation tools [41]. It demonstrates that prior knowledge can determine how well learners acquire information from hypermedia and can influence their learning patterns in a hypermedia system [4]. [22] illustrates the interaction of prior knowledge with hypermedia learning by presenting a review of relevant research covering 26 quantitative and qualitative studies from 1990 to 2003. In particular, the review focused on four themes - (1) disorientation problems; (2) content structure; (3) navigation tools; and (4) additional support - as they are considered to be important issues pertaining to hypermedia learning in the literature.

Table2 Summary of preferences for novice and expert users (From [22])

Novices	Experts
• Perform better in hierarchical structure	• Perform better in network structure
• Need advance organizers and advertisement	• Prefer free navigation
• Prefer guided navigation	
• Prefer concept maps	

Table 2 shows summary of preferences for novice and expert users derived from their study.

2.3 Cognitive Styles and AEHSs

Recent research has shifted to the exploration of incorporating cognitive styles in the adaptivity of educational hypermedia systems, such as INSPIRE [28] and AES-CS [29]. Cognitive style, which is a term used in cognitive psychology, describes the way individuals think, perceive and remember information, or their preferred approaches to using such information to solve problems. Cognitive style is sometimes used interchangeably with learning styles. However, [30] and [31] note that learning styles are the cognitive, affective, and psychological traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment. In other words, cognitive styles and learning styles are not fully the same.

Table 3: Differences between Holists and Serialists (Derived from [38])

Holists	Serialists
• Pick up bits and pieces with a broad framework • May leave gaps, or repeat themselves • May make mistakes about connections between things • May over-generalise • May be more comfortable with "topic" based learning	• Build up their knowledge sequentially • Tend to lose sight of the bigger picture • Are impatient with co-workers who" jump around" • Are more comfortable with inherently sequential problem-solving

Holist-Serialist is a dimension of cognitive style identified by Pask [32]. Pask and his colleagues conducted a series of experiments [33, 34] to determine learners' basic approaches in learning a range of complex academic topics by monitoring routes taken by learners through the topics. The experiments were set up such that the participants used one of two basic approaches, which are the global and the local approaches. In the global learning approach, termed "Holist", learners examined the interrelationships between several topics early in the learning process. They built a broad conceptual overview into which detail could subsequently be fitted. In the local learning approach, termed "Serialist", learners examined one thing at a time, and concentrated on separate topics and the logical sequence linking them. Pask found that individuals were consistent in their use of strategies of Holists or Serialists. [38] summarized the differences between Holists and Serialists, as shown in Table 3.

A number of studies found that Holists and Serialsts showed different preferences to the use of hypermedia systems. For example, [35] found significant differences in navigational tools used by Holists and Serialists. The Holists made greater use of the concept map while the Serialists of the keyword index. Additionally, [36] found that Holists spent a greater proportion of their time browsing high in the hypertext hierarchy, which was explained in terms of Holists being dependent on a need to grasp a sense of the structure of the hypertext, which differ from the browsing strategies displayed by Serialists, which did not appear to be indicative of such a need. In addition to the aforementioned works, [37] also identified the differences in the needs of Holists and Serialists in hypermedia learning, which are summarized in Table 4.

Table 4: Preferences of Holists vs. Serialists (adapted from [37])

Holists		Serialists	
Characteristic	*Preference*	*Characteristic*	*Preference*
Passive approach	Rely on a map to impose mental structure	Active Approach	Prefer to use index to locate specific items
Global tendency	Prefer breadth-first paths	Analytical Tendency	Prefer depth-first paths
Internally directed	Prefer non-linear and flexible navigation	Externally directed	Prefer linear and restricted navigation

As shown in Table 4, Holists and Serialists have very different preferences, also Table 4 showed that novice and expert users have different preferences. Thus, it is necessary to develop AEHSs, which one matches with the preferences of Holists and Serialsts, and the other matches with preferences of Novices and Experts. To this end, based on the findings in Table 4 and, we developed two AEHSs each exhibiting two types of interfaces: one AEHS has interfaces that adapt to Holists and Serialists while the other AEHS had interfaces that adapt to Novices and Experts. Prior to this study, two studies were conducted that checked whether the developed AEHSs influence learning performance [39, 40]. The results of the studies showed that both AEHSs improved learning performance. However, the studies did not make a comparative analysis to determine which of the two improved learner performance more than the other. In this vein, this study addresses this issue by investigating the research question: *Whether adapting hypermedia learning system to an*

individual's Holist-Serialist dimension shows any differences in perceptions of use when compared to adapting hypermedia learning system to an individual's prior knowledge.

3. Experimental Design

3.1 Participants

104 participants from Brunel University took part in this experiment. 60 students participated in the prior knowledge version while 44 participated in the cognitive styles version experiment respectively. The age group of the participants ranged between 18 and 30. The sample represented students from Information Systems and Computing, Mathematics and Engineering that included both undergraduate and post graduate students. The participants were chosen from such diverse disciplines and different levels of courses so that the bias of a particular type of domain knowledge or course could be reduced.

3.2 Research Instruments

3.2.1 Adaptive Educational Hypermedia System: Prior Knowledge Approach

The AEHS presents an introduction to XML (e**X**tensible **M**arkup **L**anguage). AHA! was utilized in the development of the prototype of the AEHS [15]. However, some extensions and changes to the source code of the 'open source' AHA! were created and implemented for suitability of this study

- The pre-test and post-test were incorporated into AHA! As sub-components.
- For the system to adapt to individuals with high prior knowledge, we developed a component that uses an index, instead of hierarchical content structure offered by the treeView components of AHA!

Table 5: The differences between novices' and experts' interfaces (adapted from [18];[19])

Adaptive Hypermedia	Novice Interface	Expert Interface
Link hiding	Hidden links	Rich links
Adaptive layout	Hierarchical Map	Alphabetic Index
Additional support	Advisements	No advisements
Annotated Links	Traffic light metaphor	No annotations

Four types of adaptive hypermedia techniques, including link hiding, adaptive layout, additional support and annotated links, were applied to develop these two versions, and their functionalities are detailed in Table 5.

- *Link Hiding:* The idea of links hiding, which was used in the novices' interface, is to limit the navigation space and reduce the cognitive load by hiding all links to the nodes that the student is not expected to learn. There are two kinds of these links: links to not-ready-to-be-learned nodes and links to the nodes that are outside the users' current goal. AHA! implements this adaptive technique for its content. For the links in the content, blue links meant the material behind the link was ready to be learnt, purple for learnt (or visited) material and black (similar to text, i.e. hidden) meant for material which the learner was deemed not ready to learn.
- *Adaptive Layout:* Because novice and expert users process information in different ways, adaptive layout was applied to identify the relationships of the subject topics by providing different tools. The novice interface provided a hierarchical map, which could help novices to understand the content structure. Conversely, the high prior knowledge interface used an index to facilitate the location of specific information. These tools allowed users to go directly to any page of the system, and were located in the top left-hand corner, within the sidebar.
- *Additional Support:* This was implemented in AHA! in the form of advisements and visual cues that recommended some links based on learners' prior knowledge. Furthermore, the navigational aids were used to help novices ease disorientation problems.
- *Annotated Links:* The links for low prior knowledge students were annotated to support local orientation by providing information about the current state of nodes behind the annotated links.

For experts, the guidance through the material was negligible. An index was used to navigate through topics, instead of a hierarchical map employed for novices. The content was more detailed and more advanced with links that were not annotated. The links showed only the standard browsers distinction between visited and unvisited modes.

3.2.2 Adaptive Educational Hypermedia System: Cognitive Styles Approach

The AEHS presents an introduction of XML (eXtensibleMarkup Language). AHA! was utilized in the development of the prototype of the AEHS [15]. However, some extensions and changes to the source code of the 'open source' AHA! were created and implemented for suitability of this study

- The pre-test and post-test were incorporated into the AHA! as sub-components.
- The Study Preference Questionnaire (SPQ) developed by [42] was adopted and implemented as an online component using Javascript and incorporated into the system.

Three types of adaptive hypermedia techniques, including direct guidance, link hiding and adaptive layout, were applied to develop these two versions, and their detailed functionalities are described in Table 6.

Table 6: The differences between Holist and Serialist interfaces

Adaptive Hypermedia	Holist Interface	Serialist Interface
Guidance	No guidance	Next/ Previous Buttons
Link hiding	Rich links	Disabled links
Adaptive layout	Hierarchical Map	Alphabetic Index

- *Direct guidance:* Direct guidance is the most simple technique or technology of adaptive navigation support. It is taken from intelligent tutoring systems and is usually implemented through the "next" button for the systems to suggest the best next unit of information to visit according to the user's goals and other parameters in the user model. Pask's experimental studies [32] show that the Holist is cognitively complex and likes to have several things "on the go" at the same time. In contrast to the steady "brick-by-brick" approach of the Serialist, the Holist adopts a comparatively high risk, exploratory strategy, switching attention across a range of tasks before any one is securely completed and checked as a sure foundation of further progress. This, therefore, requires no guidance that would restrict their "jumping around" approach. On the other hand, the Serialists have a narrow focus and follow a step-by-step logical progression, making sure to build solid foundations for each next move. Hence direct guidance using NEXT/PREVIOUS or BACK/ FORWARD buttons was seen as viable for the Serialist interface.
- *Link disabling:* Due to the fact that Serialist users become disoriented and prefer a linear navigation strategy, the Serialist interface provided restricted navigation choices whereby links within the body of the page were disabled, hence displayed as normal text. On the other hand, the Holist interface provided rich links within the main body of the text, leaving freedom of navigation to the users.
- *Adaptive layout:* Because Holist and Serialist users process information in different ways, an adaptive layout was applied to identify the relationships of the subject topics by providing different tools. The Holist interface provided a hierarchical map, which could help Holists to understand the content structure. Conversely, the Serialist interface used an alphabetical index to facilitate the location of specific information [35]. These tools allowed users to go directly to any page of the system and were located in the top left-hand corner, within the sidebar.

3.2.3 Pre- and Post-tests

The pre-test and post-test were conducted to assess participants' levels of knowledge of the subject domain both before and after using the systems. The pre-test gave an objective assessment of the participants' prior knowledge of the subject domain, as opposed to the subjective measure given by their responses to the perception questionnaire. Each test contained 19 multiple-choice questions covering the content of XML. For each question, there were five possible responses: four different answers and a "I don't know" option. The questions were matched on the pre-test and post-test so that each question on the pre-test had a corresponding similar (but not the same) question on the post-test. Creating similar questions was achieved by either re-writing the question or changing the answer options to TRUE/FALSE and "don't know". The questions in the post-test were also shuffled so that the number sequence was different from the pre-test. The item difficulty index was ranging from 0.27 to 0.85 which was of moderate difficulty [43]. Overall, the reliabilities of the pre-test and post-test scores were acceptable. The alpha coefficient of the pre-test scores was 0.73 while the alpha coefficient for post-test scores was 0.82.

3.2.4 Study Preferences Questionnaire (SPQ)

In an attempt to devise a relatively quick and easy measure of Holist and Serialist biases, [42] has produced the Study Preferences Questionnaire (SPQ),

which is an 18-item inventory for categorizing learners as Holists or Serialists. To this end, students were provided with two sets of statements. They were asked to indicate their degree of agreement with either statement, or to indicate no preferences [42]. As the SPQ has been used in several studies, such as [35] and [36], it was chosen for this study, which identified Holists and Serialists by using criteria suggested by the original producer [42]: (a) if users agree with over half of the statements related to Holists, they are treated as Holists; and (b) if users agree with over half of the statements related to Serialists, they are then considered Serialists, and (c) if users agreed with half of the Holist statements and half of the Serialist Statements, they are then considered as Intermediate. This study showed adequate reliability for the SPQ ($\alpha = 0.67$).

3.2.5 Perception questionnaires

The perception questionnaires were created for examining participants' perceptions to the AEHSs and OHLS. In total, the perception questionnaires included 44 statements, which were classified into four categories: "degree of confidence", "functionality and usability", "presentation and navigation" and "overall perceptions". This questionnaire, therefore, allowed for the analysis of a wide range of user perceptions so that a complete understanding of students' perceptions could be obtained. A 5-point Likert-type scale was employed to measure participants' perceptions. For example, for the question "I found the content of the tutorial too detailed", possible responses were "strongly agree", "agree", "neutral", "disagree" and "strongly disagree". Some questions were positively phrased (e.g., "I found that the suggested route through this tutorial is helpful") and others were negatively phrased (e.g., "I felt the structure of the tutorial was not clear"). The number of negative and positive statements was approximately equal to reduce any bias. The reliability of the perception questionnaires was found to be acceptable ($\alpha = 0.88$).

3.3 Experimental Procedures

In order to determine whether or not the AEHS adapting to prior knowledge (i.e. PAEHS) was better, with respect to learning performance, than the AEHS adapting cognitive styles (i.e. CAEHS), a between-subjects design was used. In other words, this meant that each student used either of the systems once but not both. The experiment was controlled. The same content was used for both systems without incurring the practice and fatigue effects in the experiment. Furthermore, each participant went through the same procedures in order to minimize bias. The following procedures were followed:

- At the beginning of each experiment, the subjects were briefed about the functionality of the system and the available tools that can be utilized to aide learning. This explanation about the functionality of the system was meant to minimize the gap between system experiences of participants as they were from diverse backgrounds and previous research has shown that system experience can have an effect on learning performance and perceptions [36, 5].
- For both PAEHS and CAEHS the subjects were then asked to, carefully, go through a pre-test which consisted of 19 questions to measure their initial levels of knowledge. To draw participants' attention to details, answers could not be changed once they have been given. The system also allowed participants to continue to the next level once all questions have been answered.
- Furthermore, for the CAEHS the subjects were automatically provided with the Study Preference questionnaire (SPQ) to determine whether the subjects are Holists or Serialsts. Subsequently, the right version of the adaptive hypermedia system was presented based on the results of the SPQ.
- When the participants had studied the material, they could then follow a link to do the post-test.
- When the participants had studied the material, they then followed a link to do the post-test. Finally, the participants were provided with the perception questionnaire to express their opinions to the use of the PAEHS or the CAEHS.

3.4 Data analyses

This study aims to compare the differences between the PAEHS and the CAEHS based on perceptions. The responses to the perception questionnaire were applied to identify the differences in their perceptions of the employed hypermedia learning system. These differences between PAEHS and CAEHS were analyzed by using Statistical Package for the Social Sciences (SPSS) for Windows (release 15.0). Following Cohen (1992), effect sizes can generally be defined as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$). The testing statistical significance for the differences between the PAEHS and the CAEHS was done by independent t-tests because they are suitable to compare the means of two independent samples [44]. A significant level of 0.05 was adopted for the study.

4. Results and Discussions

The section analyzes the perceptions of Novices and Experts towards PAEHS and, also Holists and Serialists towards CAEHS. This analyzes was done in terms of (i) Contents and Structure , (ii) Presentation and Navigation, (iii) Functionality and Usability, and (iv) Difficulties and Problems in interacting with the two AEHSs respectively. The results presented in Tables 7. The items selected from the perceptions questionnaire based on the semantic relevance of the study.

The post-test attitude and perception questionnaire consisted of four parts. The first part included nine (9) questions relating to content description and structure of the courseware. The second part included eleven (11) questions relating to presentation and navigation of the hyperspace. The third part included eight (8) questions relating to functionality and usability of the hypermedia. The fourth part included seven (7) questions relating to difficulties and problems encountered when perusing the courseware.

Table 7: t-test results of perception aspects

Perception aspects	**Prior Knowledge**	**Cognitive Styles**	**Significance**
	Mean (*SD*)	Mean (*SD*)	t(***p***)
Content and Structure: I found the content of this tutorial too detailed.	3.27 *(.83)*	2.68 *(.89)*	2.36 ***(.02)***
Difficulties and Problems: I felt the table of contents (or index) is not clear.	2.23 *(1.14)*	1.64 *(.58)*	2.21 ***(.03)***
Difficulties and Problems: I was lost using the PREVIOUS/NEXT buttons.	2.04 *(.92)*	1.55 *(.67)*	2.09 ***(.04)***
Difficulties and Problems: When I navigated this tutorial, I often forgot where I was.	2.46 *(1.17)*	1.77 *(.92)*	2.23 ***(.03)***

The overall results showed that the respective groups that used the PAEHS and the CAEHS equally enjoyed their versions in terms of Presentation and Navigation as well as Functionality and Usability. However, with respect to Content and Structure, the independent t-test results indicate that students who used the PAEHS found the content to be too detailed as compared to those who used the CAEHS. The independent t-test results also showed that students using the PAEHS experienced more problems as compared to those using the CAEHS. The students who used the PAEHS felt that their version of table of contents was not clear as compared to those who used the CAEHS. The table of contents implemented for novices was adapted from AHA! which implements a collapsible treeView while the table of contents for Holists used an expanded treeView. Furthermore, the students using the PAEHS did not enjoy the use of PREVIOUS/NEXT buttons as compared to those using CAEHS. The former also felt they often forgot where they were when navigating their adaptive hypermedia version.

These results, hence, in general suggest the learners who used the CAEHS enjoyed their system significantly more than those who used the PAEHS. This result supports the previous findings by [40] suggested that AEHSs that adapt to cognitive styles seem to have a greater effect on perceptions rather than learning performance.

5. Conclusions

The main aim of the study was to determine whether an AEHS that adapts to students' prior knowledge has more effect on perceptions than the one that adapts to their cognitive styles. The answer to the question is that AEHSs that adapt basing on cognitive styles have more effect on students' perceptions than those that adapt basing on their prior knowledge. Hence this study, together with results from [8, 39] and [40] have demonstrated that there is a need to combine prior knowledge and cognitive styles in a systematic way in order to maximise learning and comprehension in AEHSs. The AEHSs should, therefore, be designed in such a way that cognitive styles would maximise perceptions while prior knowledge driving the learning performance.

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