Accommodating Individual Differences in Web Based Instruction (WBI) and Implementation

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Abstract: Hypermedia systems have gained attraction for the purposes of teaching and learning. These systems provide users with freedom of navigation that allows them to develop learning pathways. Empirical evidence indicates that not all learners can benefit from hypermedia learning systems. In order to develop a learning environment, individual differences need to be taken into account to ensure they impact on students' achievements. In this paper, we describe and propose a web based instruction (WBI) program which accommodates preferences of individual differences; learner's prior knowledge and cognitive styles using the three key design elements of navigation tools, display options and content scope are explored. We also add learner's gender behaviour as a third dimension of individual differences.

1 INTRODUCTION

There have been numerous research studies on the effect of hypermedia on learners using Web Based Instruction (WBI), (Chen and Liu, 2008); (Torkzadeh and Lee, 2003); (Chen et al., 2006). A learner's performance is determined by their varying skills and abilities and various personal features such as age, gender, interests, preferences and background knowledge of course content. Such differences, known as "individual differences" of learners, have been found to be important human factors in the development of non-linear learning systems (Calcaterra et al., 2005); (Mitchell et al., 2005). WBI design can provide flexible navigational tools for teaching and learning in a non-linear learning approach (Pituch and Lee, 2006); (Minetou, et al., 2008); examples include a main menu, a hierarchical map or an alphabetical index and search option. In order to develop a learning environment, individual differences need to be taken into account to ensure they impact on students' achievements. This environment must be suitable for their differences, including their learning styles, preferences and needs (Samah et al., 2011). Thus, many research studies have attempted to find ways of building systems to be robust and accommodate preferences of individual differences.

In this paper, we propose a WBI program which accommodates preferences of some individual differences using mechanism provided in Chen and Liu (2008) and a framework of Chen et al., (2006). Our WBI program and its implementation consider individual differences such as learner's prior knowledge, gender, and cognitive styles (field dependent and field independent). These considerations are reflected in the three key design elements, navigation tools, display options, and content scope in the structure of our proposed WBI.

2 BACKGROUND

The web-learning environment includes various multimedia lessons such as text, animation, graphics, video and sound. It is important that trainers are easily able to recognize information resources that match user's needs. Users should have a flexible interface to accommodate their needs and should be able to identify relevant content and navigation support, freely move around and scan results. Many research studies have been engaged in finding ways to build such systems to be a robust hypermedia-learning environment that can accommodate the individual differences. Existing studies suggest that a non-linear learning approach in hypermedia learning systems may not be suitable to all learners (Chen and Macredie, 2002). Learners may have different backgrounds, especially in terms of their

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knowledge, skills and needs, so they may show various levels of engagement in course content (Wang, 2007). Therefore, many studies argue that no one style results in better performance. However, learners whose browsing behavior was consistent with their own favoured styles obtained the best performance results (Calcaterra et al., 2005); (Khalsa, 2013).

2.1 Individual Differences

Previous studies demonstrated the importance of individual differences as a factor in the design of web-based instruction. Such individual differences have significant effects on user learning in web-based instruction, which may affect the way in which they learn from, and interact with, hypermedia systems. These range from cognitive styles (Kim, 2001); (Chen and Macredie, 2004); (Workman, 2004), to prior knowledge (Hölscher and Strube, 2000); (Calisir and Gurel, 2003); (Mitchell, et al., 2005) to gender differences (Schumacher and Morahan-Martin, 2001); (Roy et al., 2003); (Beckwith et al., 2005).

The individual difference factors identified in our research to influence the learner's performance are Cognitive Styles such as Field Dependent vs. Field Independent, Prior Knowledge such as Novice vs. Expert, and Gender differences.

Gender. Navigation is an important issue in Web-based interaction. Some studies have found that there are relationships between navigation patterns and gender differences. Large et al., (2002) studied the behaviour of gender differences when retrieving information from the Web. They found that males were more actively engaged in browsing than the females. Generally, the males explored more hypertext links per minute, tended to perform more page jumps per minute, entered more searches in search engines, and gathered and saved information more often than the females, although males spent less time viewing pages than females. These findings agreed to those of Roy et al., (2003) who examined student's navigation styles. Their findings had shown that males tended to perform more page jumps per minute, which indicates that males navigate the information space in a non-linear way. On the other hand, females browsed the entire linked documents and followed a linear navigation approach.

Prior Knowledge. Learners with different levels of prior knowledge, from experts to novices, benefit differently from hypermedia learning systems (Calisir and Gurel, 2003); (Wildemuth, 2004). Many studies argue that there are different levels of perceptions in using hypermedia learning systems which require different ways to navigate (Shin et al., 1994); (McDonald and Stevenson, 1998); (Calisir and Gurel, 2003).

Torkzadeh and Lee (2003) discussed how to understand users' prior knowledge which can influence the system success directly and indirectly. The main conclusions were: (1) Users with lower domain knowledge gain more benefits from the hypermedia tutorial than those with higher prior knowledge, (2) Examples are useful vehicles for the users with low levels of domain knowledge; and (3) Users who enjoy the Web and Web-based learning are more able to cope with the non-linear interaction. Recent reviews show that the hypothesized advantages of a high level of learner control are valid for learners with high prior knowledge only (Scheiter and Gerjets, 2007); (Schnotz and Heiß, 2009); (Chen et al., 2006). Therefore, learners with high prior knowledge experience fewer difficulties and do not need additional support in navigating hypermedia systems. Moreover, some studies suggest that users with more system experience have more efficient navigation strategies than users with less experience (Fidel et al., 1999); (Hill and Hannafin, 1997); (Lazonder et al., 2000).

Cognitive Styles. Cognitive style refers to the preferred way individuals process information and research into individual differences suggests that a learner's cognitive style has considerable effect on his or her learning in hypermedia systems. Many studies use statistical methods to analyze learners' preferences (Lee et al., 2009). Moreover, in a traditional, non-multimedia learning environment, matching a user's cognitive style with content presentation has been shown to enhance performance and improve perception (Ford and Chen, 2001). Cognitive style is known as an important factor influencing learners' preferences.

There are many dimensions to cognitive styles, such as field dependent versus field independent, visualized versus verbalized or holistic-global versus focused-detailed. Discussed below is the dimension of field dependent versus field independent, which is the most common cognitive style.

Field independent learners have an impersonal behaviour. They are not interested in others and show both physical and psychological distance from people. They tend not to need external referencing methods to process information and are capable of restructuring their knowledge and developing their own internal referencing methods (Chen and Liu, 2008).

Field dependent learners have interpersonal behaviour in that they show strong interest in others and prefer to be physically close to people. They make greater use of external social influences for structuring their information. Field dependent learners are more attentive to social cues than field independent learners (Chen and Liu, 2008).

2.2 Hypermedia/Program Design Elements

Hypermedia is advancement over the traditional Computer Based Learning systems since hypermedia allows the users to choose their own path to navigate through the material available. Hypermedia also allows non-linear access to large amounts of information and provides users with greater navigation control to browse information. Hypermedia provides a flexible approach which helps users to work with the information from different points of view. Chen, et al. (2006) developed a framework to help users with various levels of prior knowledge. The aim of Chen, et al. (2006) framework was to integrate users' prior knowledge into the design of hypermedia learning systems based on the analysis of previous research. This framework includes four elements: disorientation problems, content scope, navigation tools and additional support. Those elements will be discussed below:

Disorientation Problems. Many studies argued that not all learners are able to manage the high level of links accessed by hypermedia systems. Such studies indicate that learners' prior knowledge is an important factor with significant influence. To quote: "novice hypermedia users met more disorientation problems and needed analogies with conventional structures if they were to learn successfully" (Chen et al., 2006). McDonald and Stevenson (1998) examined the effects of prior knowledge on hypermedia navigation and showed that users who lacked sufficient prior knowledge demonstrated more disorientation problems because they tended to open more additional notes; this suggests they could not recall where they had been and they had difficulties in finding the information they required.

Additional Support and Display Options. Many studies argue that hypermedia learning seems to be more suitable for expert users. Conversely, novice users experience more disorientation problems, so it is essential to provide them with additional support through mechanisms such as advisement (Shin et al., 1994), graphical overviews (De Jong and Van der Hulst, 2002) and structural cues (Hsu and Schwen, 2003).

Chen et al., (2006) argued that research in this area shows that additional support can be provided to help novices in hypermedia learning. Advisement, which provides learners with visual aids and recommended navigation paths is helpful in preventing disorientation in non-linear hypermedia learning. As novice learners cannot rely on their prior knowledge to help them structure the text, graphical overviews and structural cues are powerful and beneficial in providing navigation guidance so as to ease disorientation problems. The results in the study by Chen and Liu (2008) showed that "different cognitive style groups tend to favour different display options". Moreover, the study of Chen and Liu (2008) had shown that field-independent students are capable of extracting relevant information from the detailed description because they have a tendency to use their own internal references. However, field-dependent students rely more heavily on external cues and prefer to get concrete examples. Thus, field-dependent users look at examples, while field-independent users frequently examine the detailed descriptions.

Content Scope. Chen et al., (2006) indicated that experts focused on locating detailed information by using depth-first strategies, started from the first link on the initial site, then followed links until they found a suitable site. Conversely, novices tended to get an overview by using breadth-first strategies, following the first link of the initial site, without browsing any links in depth. Chen and Liu (2008) concluded that field-independent users tend to browse fewer pages than field-dependent users. An explanation provided in this study is that field-independent users tend to be more analytical, are very task-oriented and pay attention to particular topics related to their learning. In contrast, field-dependent users observe objects as a whole and process information in a global fashion. Thus, they tend to browse many pages to build an overall picture of the content. These findings strengthen the claim of previous research that field-independent people are good at analytical thought, whereas field-dependent people have global perceptions (Goodenough, 1976); (Witkin et al., 1977). To show additional topics for field-dependent students who would like to get a global picture of the subject content, a pop-up window can be used.

Navigation Tools. Navigation tools are used in current hypermedia learning systems, most commonly hierarchical maps and alphabetical indices, each of which provides different functions for information access. For example, hierarchical maps provide an overview of the global structure of the context, while alphabetical indices are useful for locating specific information (Chen and Macredie, 2002).

Carmel et al., (1992) found that experts were more interested in using tools that could facilitate the location of detailed information related to specific entities. Pazzani (1991) found that experts profited most from a flexible path, whereas novices benefited most from a structured path. Moreover, in the study of Möller and Müller-Kalthoff (2000), novices appeared to benefit from hierarchical maps, which can facilitate the integration of individual topics. A possible explanation for these findings is that the hierarchical map not only reveals the document structure (i.e., the physical arrangement of a document), but also reflects the conceptual structure (i.e., the relationships between different concepts). In other words, the hierarchical map can help novices incorporate the document structure into the conceptual structure, which helps them to integrate their knowledge. Research of Chen et al., (2006) had shown that experts and novices had different preferences to, and get benefit from, different navigation support. Expert learners need to have navigation tools that provide them with free navigation and find specific information that they need. Index tools, content lists and search tools are shown to be helpful for them. However, navigation tools such as map and menu tools are beneficial for novice learners in hypermedia learning systems. In Chen and Liu (2008), results showed that field-dependent and field-independent users were provided different preferences for navigation tools. Field-independent users often prefer the alphabetical index, which provides users with the means to locate particular information without going through a fixed sequence (Chen and Macredie, 2002). On the contrary, field-dependent users often use the hierarchical map to illustrate the relationships among different concepts (Turns et al., 2000) which reflects the conceptual structure of the subject content (Nilsson and Mayer, 2002).

In Table 1 we show the results of the study by Chen and Liu (2008) which can be considered as a mechanism to help designers develop WBI programs; it achieved this by accommodating the preferences of both field independent (FI) and field dependent (FD) learners. The previous discussions show that there are many studies engaged in studying learner's behaviors using hypermedia systems, trying to accommodate their preferences in the design of such systems. Using some existing designs (Chen and Liu, 2008); (Chen et al., 2006) we built our system by accommodating learner's preferences; our proposed system was conducted to provide researchers with factors may help to do investigations on the impact of individual differences after using our system. Many studies were engaged in studying the preferences and performance of learners using different measuring factors after using hypermedia systems; those measuring factors could be time, number of visited pages and gained score (Large et al., 2002); (Roy et al., 2003); (McDonald and Stevenson, 1998); (Mitchell et al., 2005); (Kim, 2001); (Chen and Liu, 2008); (Chen et al., 2006). The WBI program provides the users with hyperlinks within the hierarchical map on the right frame and an alphabetical index on the left frame as shown in Figure 1.

3 METHODOLOGY

Our WBI program presents instructions on how to complete several tasks using Microsoft PowerPoint. We chose Microsoft PowerPoint as the subject for the experiment because it has been taught to all of our students during their high school years. Furthermore, it is one subject that is taught to all of the different majors in the Higher Institute of Telecommunication and Navigation, where the experiment was conducted.

3.1 Design of the Proposed System

In our research, our objective is to use the mechanism from Chen and Liu (2008) as shown in Table 1 and the frame work of Chen et al., (2006), to develop an agile WBI program; the program should be flexible enough to offer multiple options tailored to the distinctive individual differences such as field dependent and field independent in addition to experts and novices learners. The WBI program will focus on the structure of using three key design elements such as navigation tools, display options and content scope.

Navigation Tools. Our WBI program provides the users with hyperlinks within the text based instructions, navigation tools, including a hierarchical map and alphabetical index (Figure 1).

Table 1: Results from Chen and Liu (2008). FI: Field Independent, FD: Field Dependent.

	Navigation tool		Display options		Content scope	
	Alphabetical Index	Hierarchical Map	Detailed Description	Concrete Example	Specific information	Overall Picture
FI	✓		✓		✓	
FD		✓		✓		✓

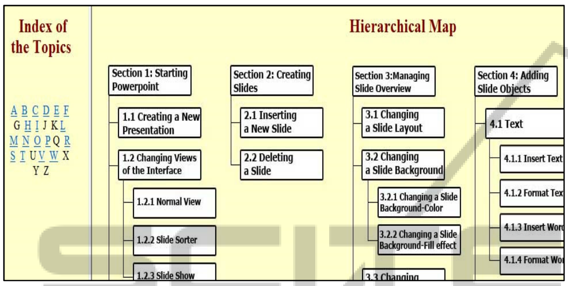

Figure 1: The main page of the WBI.

The following are the description of the window and its two frames:

1) Hierarchical Map (Figure 2): In this frame, a user can find a hierarchical structure that includes 31 topics displayed in 5 main sections. Each topic is a hyperlink when a user click on it two actions will happen, the first one is that the current window (including the left and the right frame) will be changed to another view where the chosen topic will be highlighted. At the same time the topic title will be displayed under the index on the left frame. The other action is that a popup window will be introduced to show the instructions of the chosen topic (Figure 3).
2) Index of the Topic: When the user selects a letter trying to search for a specific topic, the frame will be changed to show keywords of some topics to give the user the ability to choose a specific topic (Figure 4). However the right frame will not be changed.

Display Options. Chen and Liu (2008) state: "field-dependent students rely more heavily on external cues, thus, they prefer to get concrete guidance from examples. One of the possible ways to address their different needs is to show both of the display options, detailed description and concrete examples, within a table. By using a table, all of the relevant information about a particular case can put together in one place. For example, one column can be used to present the detailed descriptions of a particular topic, while the other column provides the illustration with examples for that topic".

In our WBI, each topic will be presented in two display options, description details and illustrated examples (Chen et al., 2006). Figure 3 shows the design of a topic page presenting the same structure (description and examples). All the topics reached from the index and map conform to the same design (Figure 3) so that we do not influence participant choice over the two different navigational tools.

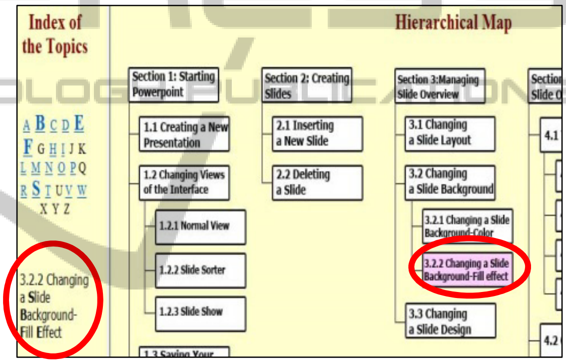

Figure 2: Chosen topic from the Hierarchical Map frame.

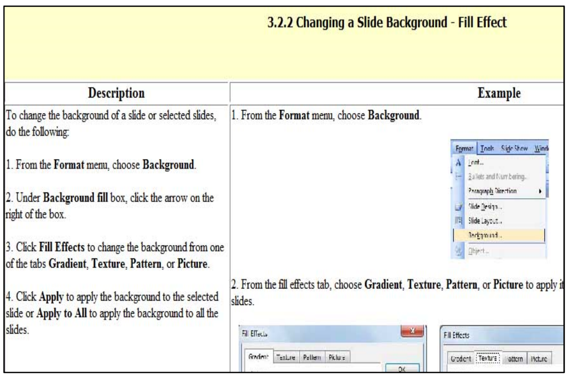

Figure 3: The webpage design of the popup window to display the topic contents.

Content Scope. Chen and Liu (2008) also state: "field-dependent students use a global approach to process information so they tend to build an overall picture by browsing more pages. One of the potential solutions to deal with their different requirements is to use a pop-up window, which is a secondary window to provide additional information about selected objects by clicking a hypertext link". The WBI program provides the users with an additional hyperlinked popup window named "Further Details" which displays deeper instructions about the topic they are currently viewing (Figure 5). A link for the Further Details' popup window can be found in the Topic window (Figure 3). The user can then close any currently opened popup windows and return to the frames page (shown in Figure 2).

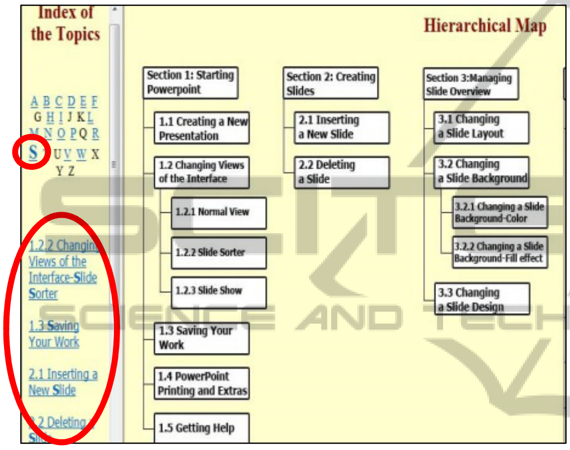

Figure 4: Topics displayed after choosing a letter from the index.

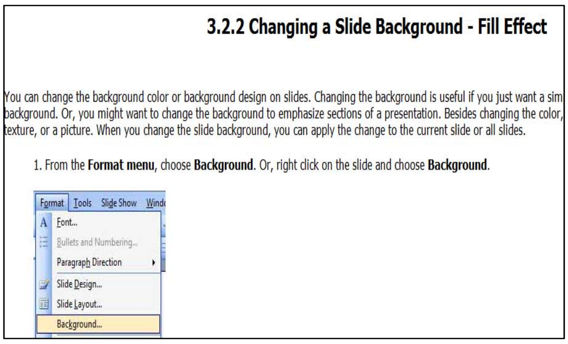

Figure 5: Displaying further details of the chosen topic.

3.2 Procedure

The experiment consisted of four phases. In Phase 1, participants were asked to refresh their prior knowledge by practicing 30 minutes on PowerPoint. Phase 2, a pre-test (a paper test prior to performing the experiment via WBI) was conducted on the participants to measure their prior knowledge (novice or expert). In Phase 3, all participants were given an introduction to the use of the WBI program highlighting the map and index navigational tools. Students were given the freedom of choice between those tools. The students were then handed out a set of tasks to complete on PowerPoint while utilizing the WBI. All of their interactions with the WBI were logged by the system. The maximum allowed time to complete the tasks was 2 hours. In Phase 4, the students were given another paper test (post-test) to measure their knowledge gain from utilizing the WBI program. Gain score (G-score) was calculated by subtracting the pre-test score from the post-test score. Both pre-test and post-test consisted of 20 multiple-choice questions. Each question had five different answers with: the "I don't know" choice being the last. Students were instructed to choose only one response. The questions on both tests targeted similar key points. However, they were rephrased on the post-test. Students were awarded one point for each correct answer.

3.3 Participants

The experiment was conducted at the Higher Institute of Telecommunication and Navigation (HITN) in Kuwait. There were a total of 91 participants with an age range of 18 to 25 years. Males and Females were studied independently during the experiment. Participants had different computing and internet skills and were classified in terms of cognitive style and prior knowledge based on the experiment. In keeping with findings from previous studies, field independent learners favored using the index navigational tool. Conversely, field dependent learners preferred to use the map navigational tool (Chen and Macredie, 2002); (Chen and Liu, 2008); (Ford and Chen, 2000). We used these findings to identify the field dependent and field independent learners using our WBI program. This was deduced by analyzing the log file of each participant.

We calculated the number of Map and Index pages that each user had navigated to. A data mining approach using Hierarchical clustering procedure was used. A hierarchical clustering procedure involves the construction of a hierarchy or tree-like structure, a nested sequence of partitions (Fraley and Raftery, 1998). Using a hierarchical clustering test, to identify learners as field dependent and field independent learners, we found that if the number of map navigated pages was more than 50% of the total navigated pages, the participant was identified as field dependent. On the other hand, if the number of index navigated pages was greater than 50% of the total navigated pages, the participant was identified as a field independent. The 50% scale is the midpoint between the two navigational methods and therefore it was considered as the cutting point between the two cognitive styles. As for the prior knowledge level of the students, novice (N) or expert (E), we calculated the mean of the pre-test scores of all the participants. If the participant's score in the pre-test was less than or equal to this mean then the participant was identified as novice (N), whereas if the participant's pre-test score was greater than the mean, then the participant was identified as expert (E). Table 2 shows number of participants after identifying them in their individual differences classes. To check the validity of our experiment from any threats or biases, firstly, the participants chosen in the experiment had an age range from 18 to 25 years who achieved high school diploma as their last educational level; this built on a foundation of similar intellectual backgrounds and exposure to computer and internet skills.

Table 2: Number of participants in each class; FD: Field dependent, FI: Field independent.

Individual differences classes	Cognitive style		Gender		Prior knowledge	
	FD	FI	M	F	E	N
Number of participants	51	40	45	46	48	43

Secondly, a pilot study was done on two participants to check the validity of the tools used in our experiment. Thirdly, we logged the display of popup pages when the participant clicks on any link in the WBI program. After observing the log file of each participant (91 participants), we removed any redundant popup pages records shown in the log file (Table 3). Those redundant records were probably caused by a lag from our remote website's server or a lag from the local network in the classroom. Redundant pages were manually removed from the log to avoid any discrepancy in our analysis. It should be noted that the logged time of the records having a fraction of a second in time difference were considered redundant. The difference (fraction of a second) in recorded time did not therefore affect the participant's total time spent on topic pages. The mean time spent on topic pages by the participants' to be 2015.36 seconds.

Finally, to minimize the error in the collected data, we eliminated the data from four participants. Three of these did not complete the pre-test and post-test of the experiment. The last one did not have a log for the interactivity with the WBI program as he/she did not utilize the WBI program to complete the requested tasks.

Table 3: A sample of the log file showing the redundant pages (bold and shaded).

Time of hitting the page	Pop-up page
1:50:01	5.1 Animating Objects On Slide frames.php
1:50:01	5.1 Animating Objects On Slide-topic.php
1:50:01	**5.1 Animating Objects On Slide frames.php**
1:50:02	**5.1 Animating Objects On Slide-topic.php**
1:50:02	5.1 Animating Objects On Slide letter.php
1:50:02	**5.1 Animating Objects On Slide-topic.php**
1:50:03	5.1 Animating Objects On Slide map.php
1:50:03	**5.1 Animating Objects On Slide-topic.php**

4 CONCLUSIONS

Many previous studies demonstrated the importance of individual differences as a factor in the design of web-based instruction. Such individual differences have significant effects on user learning in web-based instruction, which may affect the way they learn from and interact with hypermedia systems. Many studies have shown that the learners' individual differences and different system features are central matters that should be taken into account for the effective design of hypermedia learning systems. The novelty of our designed WBI system and its implementation is combining the mechanism provided in Chen and Liu (2008) and the framework of Chen, et al. (2006). Furthermore, we have integrated gender into our data analysis to identify behavioral preferences. The originality of our design was to build the whole system from the ground up to accommodate the testing environment. This has helped us to reflect on our participants' cognitive styles. Our study takes into consideration individual differences such as gender, cognitive styles, and prior knowledge using the system features such as navigation tools, additional support and content scope. These features help learners in locating information which improve the usability and functionality of WBI programs. We feel that the designed WBI using the new mechanism will help users acquire web-based content knowledge meeting their individual needs, resulting in improved learning performance and satisfaction in hypermedia environments. Moreover, investigating the impact of individual differences and the system features on learners' performance within hypermedia programs may be applied as well as studies on learners' preferences. All the data used in this paper will be made available to other users to promote replication and further studies.

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