X World Conference on Computers in Education
July 2-5, 2013; Toruń, Poland

The Effect of Individual Difference on Learning Performance Using Web-based Instruction

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Abstract
Web-Based Instruction (WBI) brings a number of benefits to individuals requiring a combination of specific learning patterns and program structure. In this paper, we propose a WBI program which suits individual differences through an existing framework and which facilitates learning by accommodating learner preferences. In particular, we make advances in three key aspects. Firstly, we study three important individual differences (gender, cognitive style and prior knowledge) as well as their interactions in the resulting learning performances. Secondly, we combined three attributes to measure performance (gain score, number of visited pages and time spent on these pages) of the three interacting individual differences. Thirdly, we investigate system features (navigation tools, additional support and content structure) to see how they can help users acquire information to meet their individual needs, resulting in an improvement in the learning performance. Two studies are presented; in one, we compare results from our program with previous studies thus evaluating its design. In the other, a data mining approach is used to investigate the effect of individual differences and how that could influence learner performance. Results indicate that performance can be affected by individual differences' behaviour. Additionally, we found that the relationship between individual differences had an even higher impact on learners' performance. The combined performance measurement attributes give a better understanding of how learners performed.

Keywords
web-based instruction, individual differences, performance

INTRODUCTION
Hypermedia systems provide users with freedom of navigation that allows them to develop learning pathways. Many studies have attempted to find ways of building hypermedia systems to be robust and which can also accommodate preferences of individual differences such as learner's prior knowledge and cognitive styles (Calcaterra et al., 2005; Mitchell et al., 2005; Samah et al., 2011). Our objective is to use models resulting from Chen and Liu (2008), and Chen et al. (2006) in designing a hypermedia system. Those studies analysed cognitive style and prior knowledge. We extend their work to include gender into our analysis. The WBI program will focus on the structure of using three key design elements (navigation tools, display options and content scope) as well as their interactions in the resulting learning per-

formance. These advances and their associated findings constitute the key contributions to knowledge in the area of hypermedia systems. We attempt to answer the following research questions: Firstly (RQ1), does the design of our developed WBI program affect learner's behaviour? Secondly (RQ2), how is a learner's performance affected by relating individual differences?

BACKGROUND

Individual differences

Most studies indicate that gender (Large et al., 2002; Roy et al., 2003) and prior knowledge, from experts to novices (Calisir & Gurel, 2003; Wildemuth, 2004), benefit differently from hypermedia learning systems. Field-dependent and field-independent are probably the most well-known division of cognitive styles. They reflect how a learner is able to restructure information based on the use of relevant cues and field arrangements (Weller et al., 1994). Field-independent learners have an impersonal behaviour and 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. Field-dependent learners, conversely, 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 (Chen & Liu, 2008).

Many studies have engaged in understanding performance of learners using web based systems. Some studies have found that males process information at a more a superficial level than females (Large, et al., 2002; Roy, et al., 2003, and Riding & Rayner, 1998). Other findings have revealed that there is no relationship between gender differences and search frequency (Hupfer & Detlor, 2006).

McDonald and Stevenson (1998) measured navigation performance in terms of speed and accuracy in answering questions and locating particular nodes. Results showed that performance of experts was better than novices. Conversely, Mitchell et al. (2005) measured the performance by gain score calculated as scores of post-test minus pre-test. They found that novices made a greater improvement on the post-test. Moreover, Ford and Chen (2000) found that experts could browse more pages than novices. Kim (2001) investigated how differences in cognitive style and online search experience influenced the search. The findings show that online search experience affected navigational style, whereas cognitive style influenced search time. Experienced searchers tended to initiate jumps more frequently than novices. Additionally, field dependent learners spent longer search time than field independent learners. Thus, for number of visited pages, studies have found that male, field-dependent, and experts browse more pages than female, field-independent, and novices (Chen & Liu, 2008; Ford & Chen, 2000; Large, et al., 2002; Roy, et al., 2003). As for time spent in browsing WBI programs, some studies have found that male and field-independent users spent less time than female field-dependent (Chen & Liu, 2008; Lee, et al., 2009; Roy, et al., 2003). Other studies have found that novices achieved a higher g-score than experts (Mitchell, et al., 2005; McDonald and Stevenson, 1998). However, there is a lack of studies demonstrating the influence of related individual differences on learners' performance using such measurements together after interacting with a WBI system.

System features

We relied in our design on three major elements of findings in Chen et al., (2006) which are additional support, content structure, and navigation tools. Additional support, such as, graphical overviews and structural cues provide navigation guidance to novices to ease potential disorientation problems (Chen et al., 2006). Moreover, field-dependent users look at examples, while field-independent users frequently examine detailed descriptions (Chen & Liu, 2008). As for content structure, findings in Chen et al., 2006 indicate that experts focused on locating specific information while novices tended to get an overall picture. A field-independent user performs well in terms of analytical thought, whereas field-dependent users have global perceptions. A global picture of the subject can be assisted with pop-up windows (Chen & Liu, 2008). As for Navigation tools, Chen et al., 2006 showed that index tools were helpful for experts., map tools were beneficial for novice. Field-independent users often prefer an alphabetical index, whereas field-dependent users often use a hierarchical map (Chen & Liu, 2008; Farrell & Moore, 2001; Chen & Macredie, 2010). Table 1 shows the results of Chen and Liu (2008).

Table 1: Results from Chen and Liu (2008)

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

Data mining

Data mining is the process of discovering interesting, unexpected or valuable information from large amounts of data (Hand, 2007). Data mining can be divided into clustering, classification and association rules (Witten et al., 2011). Clustering methods may be grouped into hierarchical and non-hierarchical (Jain & Dubes, 1999). A hierarchical clustering procedure involves the construction of a hierarchy or tree-like structure, which is a nested sequence of partitions (Fraley & Raftery, 1998); a non-hierarchical or partitioned procedure concludes with a particular number of clusters at a single step. In our attempt to answer RQ2, we have relied on applying data mining to group users into clusters; a Two-Step Cluster method was used because of its ability to automatically find the optimal number of clusters.

METHODOLOGY DESIGN

Research Instruments

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 was taught to all students during their high school. Furthermore, it is one subject that is taught to all majors in Higher Institute of Telecommunication and Navigation (HITN) in Kuwait, where the experiment was conducted. Keeping the idea of data collection in mind, while we were building the system, we chose to log every action from every participant during their use of the WBI program. Every record in the log-file included a unique name for every participant, time of the clicked hyperlink, and name of the targeted page by the clicked hyperlink.

We modified both pre-test and post-test. They consisted of 20 multiple-choice questions to assess each participant’s knowledge before and after using the program. Each question had five different answers with "I don’t know" choice being the last. Students were instructed to choose only one response. Questions on both tests targeted similar key points but were re-phrased on the post-test (Mitchell, et al., 2005). Students were awarded one point for each correct answer. A pilot study was conducted to check the validity of our system. “I don’t know” option was added later to modify both pre-test and post-test. This option was added to avoid any bias in participant answers (they might choose any answer randomly when they do not know the correct one).

Participants

Participants were a total of 91 with an age range of 18 to 25 years. All participants were experienced internet, and had at least solid basic computer skills which help them interacting with web based instruction. Males (M) and Females (F) were identified during the experiment. We used the log-file to identify field-dependent (FD) and field-independent (FI) learners. Previous studies found that FD learners preferred using map pages and FI learners preferred using index pages (Chen & Liu, 2008; Farrell & Moore, 2001; Chen & Macredie, 2010). We calculated number of Map and Index pages that each user had navigated to. We used a subjective classification system in identifying FI and FD learners. As for the prior knowledge level of students, novice (N) or expert (E), we calculated the mean (=8.5 out of possible 20) of the pre-test scores of all the participants. If a participant's score in the pre-test was less than or equal 8 then the participant was identified as novice, whereas if the participant's pre-test score was greater than or equal to 9, then the participant was identified as expert. The range between scores 8 to 9 was taken as middle third. Table 2 shows number of participants after identifying them using three individual differences.

Table 2: Number of participants in each class

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

Procedures

The experiment consisted of four phases. In Phase-1, participants were asked to refresh their knowledge by practicing 30 minutes on PowerPoint. In Phase-2, a pre-test was conducted to assess a participant's prior knowledge. In Phase-3, participants were given an introduction to the use of the WBI program. Our WBI program covered 31 different PowerPoint topics. Participants 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 Participants were given another paper test (post-test) to measure their gain score (g-score) by subtracting pre-test score from post-test score.

RESULTS AND DISCUSSION

In the first study, we compared the means of each output. For each individual differences, we calculated the mean of their g-score (mean of pre-test scores subtracted from mean of post-test scores). From the log-file, we also collected the total number of topics pages visited which displayed the topic content (t-pages) and the total time spent in the topics pages in seconds (t-time). In Table 3 we show the mean values calculated for each of the individual differences, mean of each of t-pages, t-time, g-score, pre-test scores, and post-test scores. Each variable was found to be normally distributed.

Table 3: Compared means of each individual difference

		t-pages	t-time	g-score	Pre-test	Post-test
Prior Knowledge	E	14.23	1,891.19	1.67	11.19	12.85
	N	16.60	2,153.98	4.00	5.56	9.56
	Sig.	>0.05	>0.05	<0.05	<0.05	<0.05
Gender	F	13.50	2,211.43	2.39	8.93	11.33
	M	17.24	1,814.93	3.16	8.11	11.27
	Sig.	<0.05	>0.05	>0.05	>0.05	>0.05
Cognitive Style	FI	15.83	1,765.33	3.65	8.40	12.05
	FD	14.98	2,211.47	2.08	8.63	10.71
	Sig.	>0.05	<0.05	<0.05	<0.05	<0.05

To study learner behaviour, we compared means using a Matrix Comparison. We compared the means horizontally (by rows) and vertically (by columns) using Table 3. The horizontal comparison showed that:

In terms of prior knowledge, novices achieved a higher g-score than experts. However, experts visited less t-pages and spent less t-time. In terms of gender, males achieved a higher g-score than females. Moreover, females visited less t-pages and spent more t-time.

Table 4: Evaluation of findings with previous studies

Findings of Previous Studies		**Our Findings**	**Our Other Findings**
Number of Topic Pages Visited			
M visited more pages per minutes than F	(Large, et al., 2002; Roy, et al., 2003; Riding & Rayner, 1998)	Supported	FI browse more pages than FD N browse more pages than E
FI browse fewer pages than FD	(Chen & Liu, 2008)	Not supported	
E browse pages more than N	(Ford & Chen, 2000)	Not supported	
N visited more nodes than E	(Kim, 2001)	Supported	
Time Spent in Topic Pages			
M spent less time on pages than F	(Large, et al., 2002; Roy, et al., 2003)	Supported	
FI spent less time navigating. FD spent more time navigating.	(Lee, et al., 2009; Kim, 2001)	Supported	
N spent more time than E	(Kim, 2001)	Supported	
g-score			
N achieved higher g-score than E	(Mitchell, et al., 2005; McDonald and Stevenson, 1998)	Supported	M achieved higher g-score than F FI achieved higher g-score than FD

In terms of cognitive style, field-independent learners achieved a higher g-score than field-dependent learners. Moreover, field-independent subjects visited more t-pages and spent less t-time. In terms of number of pages visited, we found that novices, males and field-independent learners visited more t-pages than experts, females and field-dependent learners. In terms of time spent on reading topics pages, we found that experts, males and field-independent learners spent less time on t-pages than females, novices and field-dependent learners.

In terms of g-score, we found that novices improved more than experts since their g-score were generally higher than experts. Males achieved a higher g-score than females and field-independent learners had a higher g-score than field-dependent learners. In our attempt to answer RQ1, we evaluate our findings in Table 4 which shows the conformity (or otherwise) between our study and previous studies.

Study 2 used ‘Two-Step Cluster’. This test is an exploratory data mining technique used to reveal clusters in a dataset which are not necessarily obvious using ‘traditional’ statistics. As a result of the clustering method, learners were grouped into five clusters; Table 5 shows number of participants in each cluster and number of individual differences allocated in each cluster. For example, 21 participants allocated in cluster-1 with 21 females, no males, no experts, 21 novices, 3 field independent and 18 field-independent learners. Table 6 shows comparison of mean values for each cluster with the global mean value of all participants: Cluster-4 has the highest number of participants, whereas the lowest number was allocated to cluster-5 (Table 5). In Table 6, results show that the highest g-score was in cluster-5 and the lowest in cluster-3. Additionally, we find that highest t-time was in cluster-1 and the lowest in cluster-5. Moreover, the highest number of t-pages was in cluster-5 and the lowest in cluster-3.

Table 5: Cluster Distribution Frequencies

Cluster	Participants	F	M	E	N	FI	FD
1	21	21	0	0	21	3	18
2	16	0	16	9	7	0	16
3	17	17	0	17	0	0	17
4	22	8	14	22	0	22	0
5	15	0	15	0	15	15	0
Combined	91	46	45	48	43	40	51

Table 6: Clusters Profiles

	g-score			**T-time**			**T-pages**		
Cluster	Mean	Mean level	Std. Deviation	Mean	Mean level	Std. Deviation	Mean	Mean level	Std. Deviation
1	3.67	High	2.517	2,442.19	High	1,369.052	15.05	Low	9.677
2	1.81	Low	2.428	1,948.81	Low	964.253	16.50	High	6.782
3	0.76	Low	2.195	2,233.24	High	1,357.356	13.24	Low	6.340
4	2.64	Low	2.150	1,775.23	Low	920.305	13.95	Low	6.779
5	5.00	High	3.094	1,594.07	Low	440.043	19.00	High	4.158
Global mean values	2.77		2.785	2,015.36		1,105.759	15.35		7.268

Figure 1 shows a summary of the shared characteristics of individual differences allocated into each cluster.

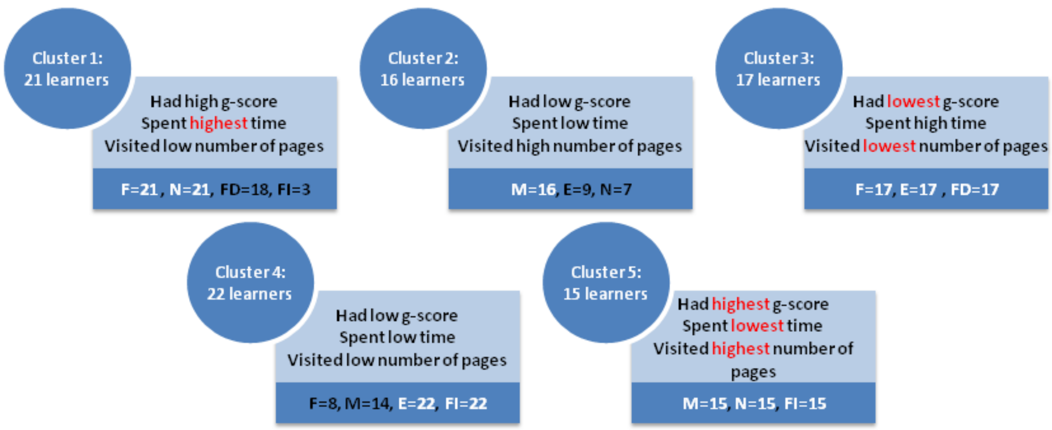

Figure 1: Results of related individual differences

We next compared between clusters according to continuous variables. These comparisons are shown in Figures 2, 3 and 4. Males browsed more t-pages than females; this finding is consistent with the findings of Large, et al. (2002), Roy, et al.

(2003), and Riding & Rayner, 1998. We found that novices browsed more t-pages than experts; this finding is inconsistent with the findings of Ford and Chen (2000). In our study, we found that males spent less t-time than females. This finding is consistent with the findings of Large, et al. (2002) and Roy, et al. (2003) that males spend less time than females in visiting pages. We also found that field-independent learners spent less t-time than field-dependent. This finding is consistent with the findings of Lee, et al. (2009) and Kim (2001) that field-independent learners spent less t-time than females in visiting pages. From Figure 4, 36 novices of a total 43 are located in clusters 1 and 5, where those clusters contain learners who achieved a high g-score. This finding is consistent with both that of McDonald and Stevenson (1998), and Mitchell, et al. (2005).

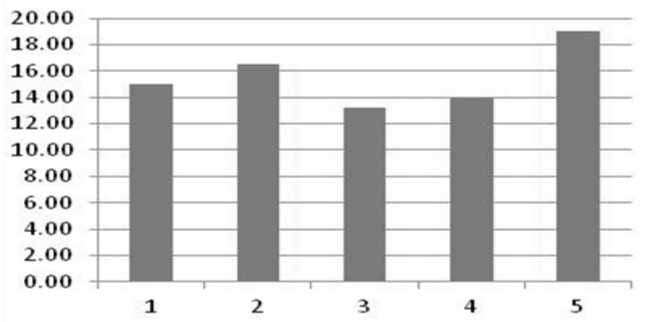

Figure 2: Mean values of t-pages visited in each cluster

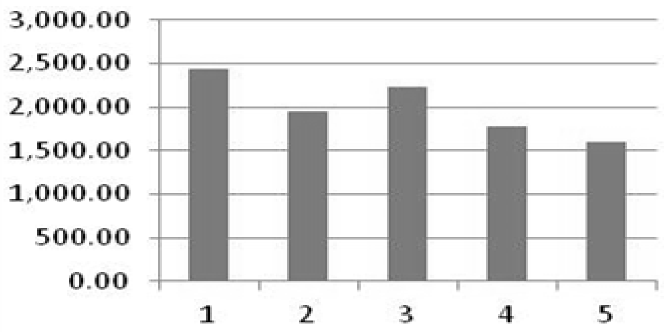

Figure 3: Mean values of t-time in each cluster

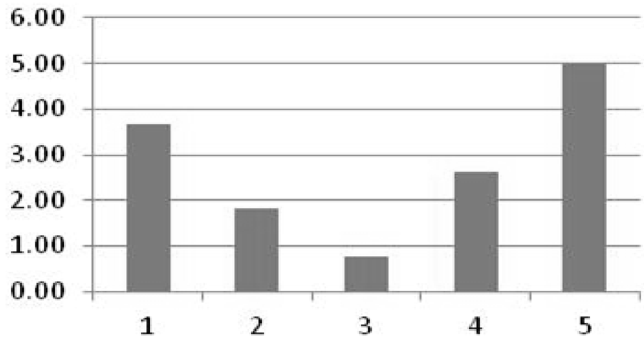

Figure 4: Mean values of g-scores in each cluster

As a result of Study 1 and in answering RQ1 (Does the design of our developed WBI program affect learner's behaviour?); we found evidence to support the view that our WBI program did indeed affect learner's behaviour. Table 4 shows that our findings from our WBI program have matched almost 75% of existing studies' findings. Therefore, the evidence can be clearly marked by observing Table 3 which indicates that our novices, males and field-independent participants had the highest knowledge gain from utilizing our WBI program. Results from Study 2 helped us answer RQ2 (How is a learner's performance affected by relating individual differences?). By applying data mining methods to our collected data (Two-Step Cluster) we have related several individual differences into five clusters. Figure 5 answers RQ2 by demonstrating related individual differences and their effect on their learning behaviour as follows:

1. Learners, who have low g-score, low t-time and high t-pages are males who are field-dependent.
2. Learners, who have high g-score, low t-time and high t-pages are males who are novices and field-independent.
3. Learners, who have high g-score, high t-time, and low t-pages are novices who are females.
4. Learners, who have low g-score, low t-time, and low t-pages are experts who are field-independent.
5. Learners, who have low g-score, high t-time and low t-pages are females, who are experts and field-dependent.

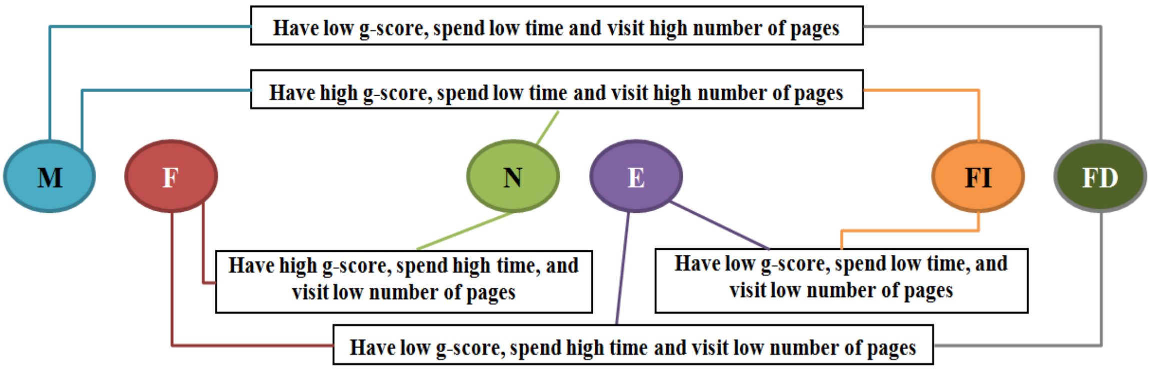

Figure 5: Conclusion of related individual difference

CONCLUSIONS

The aim of this paper was to examine the gender, prior knowledge and cognitive style as individual differences in learning behaviour while using Hypermedia systems. We built a WBI program to be used in data collection for the participants in the experiment. Our findings demonstrate that such individual differences have an impact on learner's behaviour. Few previous studies have been carried out to investigate system features (navigation tools, additional support and content structure) to see how they can help users acquire information to meet their individual needs; we have extended previous work (Chen & Liu, 2008; Chen et al., 2006) into the study of an important individual difference (gender) as well as their interactions in resulting learning performances. Additionally, it is shown that it is essential to take into account the learner's identification using more than one of the individual differences to understand his/her behaviour in using web based systems. The preferences that have been accommodated which are based on three system features presented by Chen & Liu (2008) and Chen et al. (2006) were suggested to play an influential role in student learning patterns within WBI program. More investigations on how each learner interacted with the three system features can be handled as a future work. These three advances and their associated findings constitute the key contributions to knowledge in the area of hypermedia system. As future study, a comparison between identifying learners using our system and other standardized tests would be an interesting investigation. Also, there is a need to analyse learners' navigation behaviour using other clustering algorithms or even other data-mining approaches (e.g., classification and association rules).

REFERENCES

Calcaterra, A., Antonietti, A., & Underwood, J. (2005). Cognitive style, hypermedia navigation and learning. *Computers & Education*, 44(4), 441-457.

Calisir, F., & Gurel, Z. (2003). Influence of text structure and prior knowledge of the learner on reading comprehension, browsing and perceived control. *Computers in Human Behavior*, 19, 135–145.

Chen, S. Y., & Liu, X. (2008). An Integrated Approach for Modeling Learning Patterns of Students in Web-Based Instruction: A Cognitive Style Perspective. *ACM Transactions on Computer-Human Interaction*, 15 (1).

Chen, S. Y., & Macredie, R. D. (2010). Web-based interaction: A review of three important human factors. *International Journal of Information Management, 30*, 379–387.

Chen, S. Y., Fan, J., & Macredie, R. D. (2006). Navigation in hypermedia learning systems: experts vs. novices. *Computers in Human Behavior*, 22, 251–266.

Farrell, I. H., & Moore, D. M. (2001). The effect of navigation tools on learners' achievement and attitude in a hypermedia environment . *Journal of Educational Technology Systems, 29*(2), 169–181.

Ford, N., & Chen, S. (2000). Individual differences, hypermedia navigation and learning: an empirical study. *Journal of Educational Multimedia and Hypermedia*, 9, 281–311.

Fraley, C., & Raftery, A. E. (1998). How Many Clusters? Which Clustering Method? Answers Via Model-Based Cluster Analysis. *The Computer Journal*, 41(8), 578-588.

Hand, D. J. (2007). Principles of Data Mining. *Drug Safety*, 30 (7), 621-622.

Hupfer, M. E., & Detlor, B. (2006). Gender and web information seeking: A self concept orientation model. *Journal of the American Society for Information Science and Technology, 57*(8), 1105–1115.

Jain, A., & Dubes, R. (1999). Data clustering. *ACM Computing Survey*, 31, 264-323.

Kim, K. S. (2001). Implications of user characteristics in information seeking on the world wide web. *International Journal of Human-Computer Interaction*, 13(3), 323-340.

Large, A., Beheshti, J., & Rahman, T. (2002). Gender differences in collaborative web searching behavior: an elementary school study. *Information Processing and Management: an International Journal*, 38(3), 427–443.

Lee, M. W., Chen, S. Y., Chrysostomou, K., & Liu, X. (2009). Mining students' behavior in web-based learning programs. *Expert Systems with Applications, 36*, 3459–3464.

McDonald, S., & Stevenson, R. (1998). Effects of text structure and prior knowledge of the learner on navigation in hypertext. *Human Factors*, 40, 18 –27.

Mitchell, T. J., Chen, S. Y., & Macredie, R. D. (2005a). Hypermedia learning and prior knowledge: domain expertise vs. system expertise. *Journal of Computer Assisted Learning*, 21, 53–64.

Riding, R. J., & Rayner, S. G. (1998). *Cognitive styles and learning strategies.* London: David Fulton.

Roy, M., Taylor, R., & Chi, M. T. (2003). Gender differences in patterns of searching the web. *Journal of Educational Computing Research*, 29, 335–348.

Samah, N. A., Yahaya, N., & Ali, M. B. (2011). Individual differences in online personalized learning environment. *Educational Research and Reviews* , 6(7), 516-521.

Weller, G. H., Repman, J., & Rooze, G. E. (1994). The relationship of learning, behavior, and cognitive styles in hypermedia-based instruction: Implications for design of HBI. *Comput. Schools, 10*(3-4), 401–420.

Wildemuth, B. M. (2004). The effects of domain knowledge on search tactic formulation. *Journal of the American Society for Information Science and Technology*, 55(3), 246-258.

Witten, I. H., Frank, E., & Hall, M. A. (2011). *Data Mining: Practical Machine Learning Tools and Techniques. 3rd edition.* Morgan Kaufmann Publishers.

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