Students learning style and attitude with information visualization

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Abstract: This study focuses on how learners process information visualization by exploring the relationship between fifty undergraduate learners' performance and their viewing behaviors gained from eye tracking. Furthermore, students' learning styles was investigated through different deployed learner attention. Learner preferences towards the usage of information visualization content for learning was discussed through qualitative and quantitative results. These results explored the in-depth understanding of learner behavior while learning from visual content such as areas of interest, time spent on object, visual paths and frequency of visits to an object.

Background: The visual representation of information delivers ease in learning. Tufte (1990) stated that information presented as visual instructions helps and affects learning by providing large chunks of information communicating faster than textual representation. According to Zhang, Zhou, Briggs, and Nunamakerjr (2006) multimedia based training systems provides the same level of effectiveness as face-to-face instruction in both teaching and learning.

Therefore it is important to investigate how Human brain processes and understand the complex visual information. It is indeed essential to understand how learners' understand the information presented visually and what are the key factors that affect learning. In order to improve learning effectiveness it is important to optimize the learning process by understanding the viewing behavior of learners with different learning preferences. Previously, the think-aloud protocol based interview was frequently used technique to investigate cognitive activities during learning (LeCompte & Preissle, 1993; Mintzes, Wandersee, & Novak, 1999). In recent years the eye tracking method has became the center of attraction for researchers to study basic cognitive processes during learning and information processing (Rayner, 1998, 2009). This technique is significant as it can recode the online cognitive activities, which can track the cognitive process of learning. It can provide in-depth cognitive data by observing the eye movement and its areas of interest. Such as: where the participants are looking at (Eye fixation) and for how long do they look at one object (Fixation Duration) and how they move from one object to another (Viewing path) (Holsanova, J., Holmberg, N., & Holmqvist, K. (2009)).

It is important for the educator to understand the learning styles of the learners. This research is intended to investigate the learning style through learner preferences of the participants by acquiring eye tracking data. Every individual has his own experiences, preferences and motivation in his learning processes. Learning styles refer to an understanding method that is presumed to be in the best interest of an individual. Keefe (1991) defined learning style as an indicators of how learners observe, interact with, and respond to the learning environment and also learning style is a characteristic of the cognitive, affective, and physiological behavior. Kraus, Reed and Fitzgerald (2001) stated that learning style is "the focus of an individual's preferred method for receiving information in a learning environment". With this we can understand learning style to be a characteristic preferences of how people take in and process information. Every individual student has his/her unique way of learning. According to Just and Carpenter (1976) the "Eye-Mind" assumption related to eye tracking is, what a person is looking at indicates what he/she is thinking of or attending to. Thus collecting and analyzing eye tracking data leads to derive learning preference of an individual to achieve learning style.

Research Questions: The purpose of this study was finding the relationship between learners' performance and learning style with eye fixation measures overall and for specific area of interests AOI. Also, this study seeks to create a more comprehensive understanding of how do learners view visual information and what is there attitudes toward graphics as a source of information.

Method: This study followed a mixed method design to obtain quantitative and qualitative answers to the research questions. The researchers employed multiple regression analysis to examine how eye fixation measures and learning styles influenced learners' performance, and triangulation of data sources to validate the quantitative results. The dependent variable here was learners' performance and the independent variables were the learning styles and the eye fixation measures, which are fixation duration, number of fixation, and number of visits to a specific AOI. Eye-tracking visualization tools like heat maps and eye paths were used to examine how

learners' view the visual information. Finally, personal interviews were conducted to explore the learner's attitude towards obtaining information from graphical content.

Subject: This study was conducted at a university in the central region of Saudi Arabia, with a convenience sample of approximately fifty learners. Ten students were randomly selected for interviews from the total fifty learners.
Material: The researchers used the, "Rising Sea Levels," graph from McCandless's book (2009) to conduct the study. This graph predicted the flood impact upon cities in the event of an increase in sea level.
Procedure: Learners were approached in public areas on campus with minimal disruption. They were asked to participate for approximately ten minutes. They were given a cover letter and consent form, and after their approval, they began an eye-tracking calibration, and started the task. Upon completion of the task, they took a test. After the test, learners were randomly selected for an interview.

Results:

To answer the research questions, correlation and regression analysis has been conducted. There is week Sperman's rho correlation between learning style with the eye tracking variables and performance at the level 0.05 level. This finding indicates that whenever the participants preferred the verbal learning style it slightly contribute it to higher score of Number of Fixation on AOI, Fixation Duration on AOI, Number of Fixation of whole graph, Fixation Duration of whole graph, Number of Visits to AOI.

Binary Logistic Regression has been conducted. The statistical analysis revealed that there are no variables contributed to predicting the learning style at the significant level 0.05. This may be due to that the majority of the sample prefers visual learning style than verbal learning style (see Table 2)

Table 1 Descriptive Statistics for the variables

Items	n	Mean	Std. Deviation
Performance	50	2.180	1.304
Number of Fixation on AOI (count)	50	116.100	89.463
Fixation Duration on AOI (in secs.)	50	0.355	0.079
Number of Fixation of whole graph (counts)	50	295.240	217.198
Fixation Duration of whole graph (in secs.)	50	0.353	0.079
Number of Visits to AOI (counts)	50	22.000	15.802

Table 2 descriptive statistics of the learning style

Number	Attitude Labels	N	%
1	Verbal little better than the visual	4	8.0
2	verbal and visual is the same	2	4.0
3	Visual little better than the verbal	11	22.0
4	Visual greatly better than the verbal	33	66.0
	Total	50	100.0

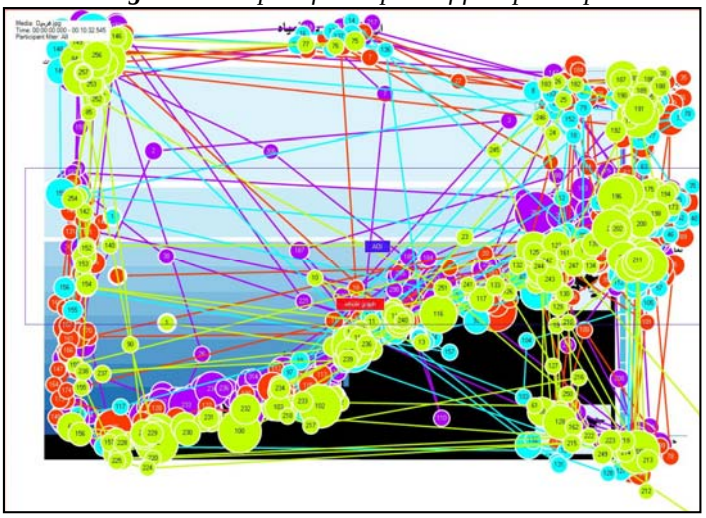
Number and percent of the Attitude Labels shows that the Majority prefer visual than verbal

In addition, there was no significant correlation between Performance and Fixation Duration of the Whole Graph at significance level , R= 0.015 , t statistics = 0.101 , and P-value = 0.920 > 0.05. However, there

was a correlation between performance and the number of fixation on the whole graph at the significance level, R= 0.291, t statistics = 2.105, and P-value = 0.041 < 0.05. Number of fixation and fixation duration for the AOI showed no relationship with the learners' performance. However the correlation between number of visits on the AOI and performance resulted in a significant correlation with R=0.276, t statistics = 2.204, and P-value = 0.042 < 0.05. The two correlations were consistent with those from a number of earlier studies. However, those earlier studies showed stronger relations. (Liu & Chuang, 2011; Rayner, Yang, Schuett, & Slattery, 2013; Schmidt-Weigand, & Scheiter, 2011; Yang et al., 2013). It was assumed that the graph was easy to understand and learners do not need longer time to process information "Longer fixations are generally believed to be an indicator of a participant's difficulty in extracting the information from a display" (Jacob & Karn, 2003, p.585). Significant relationships were found between the performance and number of visits (p-value 0,042 0.050). When learners make more visits to the central area in the graph, there performance increase. Figure 1 shows the eye movement of learners, while comparing how the level of the sea changed through the years while going back and forth between the maps. The finding revealed that the time of fixation duration couldn't be predicted from the learners' performance. An explanation could be that the given graph was not complicated and required less processing time. Also, performance test measures specific number, which was hard to recall due to the high load of information visualization.

Figure 1 shows sample of scan path of the four participants view. The sample path supported comprehensions of individual participant's behavior through the plotted starting points, fixation location, and durational indicator. The learners viewed the picture as a whole and studied the picture's details. The graph shows that the learners spent more time on the right side of the picture due to the amount of information.

Figure 1. *Sample of scan path of four participants view*



In figure 2 the sample of scan path of one participant's shows that the patters of view were in two main directions, horizontal and vertical. This was due to the figure design of the information being arranged in the graph edges. This figure shows that the learners use compare and contrast to make meaning of the graph. This can be seen in the horizontal and vertical lines. Some variables needs more time to understand than others. This can be seen in the verity of circles size.

Figure 2. Sample of scan path of a participant view

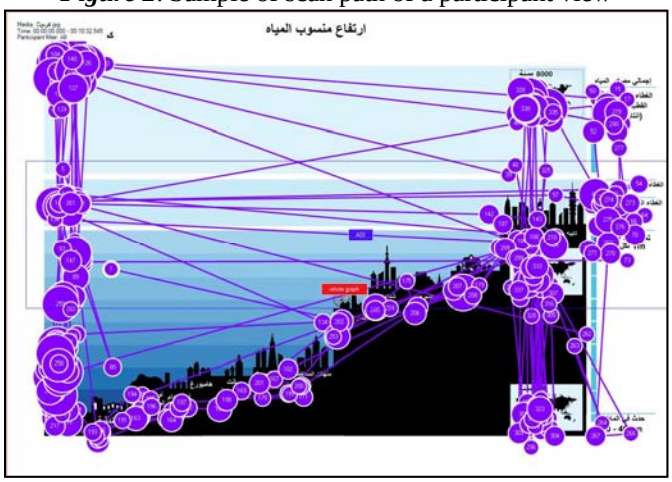


Figure 3 shows the heat map of the participants view. Heat map indicated the highest viewed area by distinguishing it in a distinct color, which is on the right side of the sea level graph. As Jacob and Karn (2003) stated, "the number of fixations on a particular display element (of interest to the design team) should reflect the importance of that element" (Jacob & Karn, 2003, p. 585). In Figure 3, the colors Red, Yellow and Green represents the most, normal and least important areas viewed by the participants respectively.

Figure 3. The heat map of the participants view

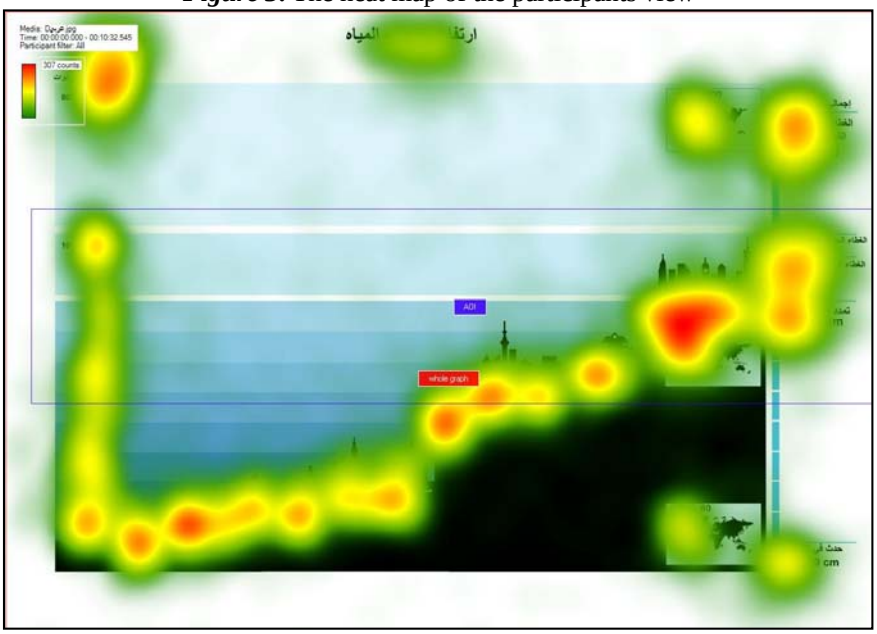
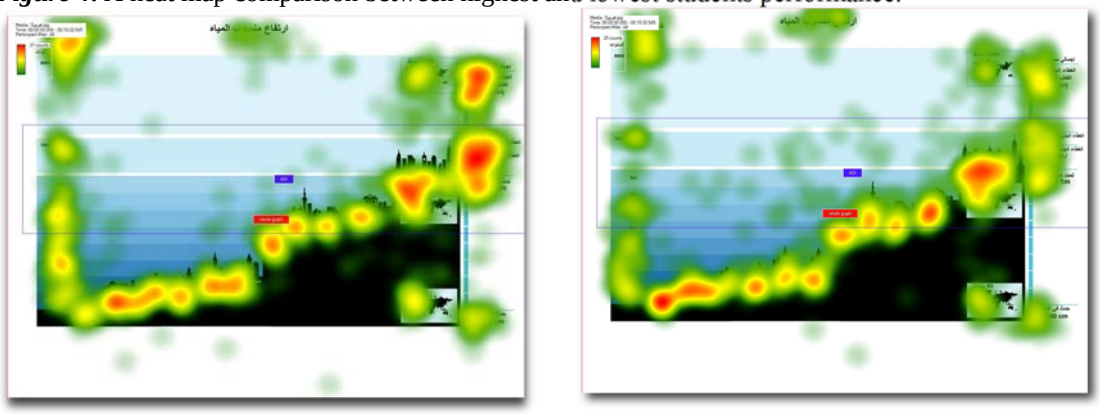


Figure 4 shows a comparison between the highest five grades and the lowest five grade students heat maps. Heat maps show a higher attention on different information for the higher grade learners than the lower grade learners. Furthermore, higher grade learners has less attention on the middle part of the map that has less information than the lower attention learners. This is consists with what Rayner (1998) points out that longer fixation duration are generally indicative of more extensive processing which does not correspond to the current study.

Figure 4. A heat map comparison between highest and lowest students performance.



High Performance Low Performance

Moreover, Learners found the Rising Sea Levels graph interesting and fun for studying. Also, learners' attitude indicated that they found graphics helpful in understanding the information "I understand the graph quickly and easily", "I like to see the information visually, I can remember it for a longer period of time". Also learners thought that the graph helped them to remember the information and recall it easily, "I do not remember every single city, but I got the main idea about how sea level affects the earth", "I can remember some of the main cities like New York", "and the graph is there in my mind, I can recall it". However some learners indicated that the concept is complicated, "it is hard to remember everything, and there is so much information". This concludes that the learners form two levels of understanding, the conceptual idea and the specific information such as the city name. Moreover, the graph has helped the learners to recall information and easily understand the concept.

This study focused upon information visualization graph with complexity in order to investigate learners' performance and learning style with eye fixation measures. However it is recommended to conduct further qualitative studies based upon multiple images with different levels of complexities. It will provide more detailed understanding of cognitive multimedia learning, learner experiences and learning styles and preferences perceptions. Furthermore, additional studies can be carried out to measure analytical abilities through visual information of groups based upon gender, IQ (Intelligence Quotient) and educational qualifications.

The possibilities of research studies with these instruments are unlimited. Studies that explore cognitive activities on Complex charts, graphs and maps, differences between general images, images with voice over and images with interactivity will be beneficial for the designers and developers to prepare more appropriate graphical content. Further studies needed related to multimedia learning based on color-coding while designing instructional material and diverting learners' attentions to a defined area of interest. It will provide firm background and guidelines for the instructional designers and developers to develop effective multimedia enriched pedagogical agents that communicate efficiently with the learners and their learning styles.

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