Understanding Effects of Presentation on Concept Learning in Technology Supported Learning

Nivedita Singh

Follow this and additional works at: https://scholarworks.rit.edu/theses

Part of the Graphics and Human Computer Interfaces Commons

Recommended Citation

This Thesis is brought to you for free and open access by RIT Scholar Works. It has been accepted for inclusion in Theses by an authorized administrator of RIT Scholar Works. For more information, please contact ritscholarworks@rit.edu.
Understanding Effects of Presentation on Concept Learning in Technology Supported Learning

by

Nivedita Singh

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Human Computer Interaction

Rochester Institute of Technology

B. Thomas Golisano College of Computing and Information Sciences

Department of Information Sciences and Technologies

06/13/2013
Rochester Institute of Technology
B. Thomas Golisano College
of
Computing and Information Sciences
Master of Science in Human Computer Interaction

Thesis Approval Form

Student Name: Nivedita Singh

Thesis Title: Understanding Effects of Presentation on Concept Learning in Technology Supported Learning

Thesis Committee

Name          Signature          Date

Evelyn Rozanski
Chair

Michael Yacci
Committee Member

Anne Haake
Committee Member
Abstract

The world of technology has had a significant impact on learning and instructional domain. Today, a large number of devices and software are specifically designed to afford faster and effective learning and instruction. They have not only erased the physical boundaries to resources in education but have also helped create new interactions and engagements for learners and instructors. With this changed scenario, the content or instructional material also needs our attention to become usable and compatible with the changed learning styles and preferences of the learners today. Not only does the content need to seamlessly integrate with the delivery methodology and technology but also utilize the capabilities offered by it to enhance the learning experience. For higher order learning content such as concepts and principles that involve deeper cognitive processes, there is a need to understand how instructional material can be made more effective in technology supported environment.

The goal of this experimental study was to investigate if conceptual learning in electronically delivered self-paced format can be made more usable and effective with right amount of content and presentation. It presented stimulus (concept attributes) in five different variations of information presentations and made a comparative assessment of performances using post-stimulus questions as a measure of a learner’s ability to generalize a concept. The eye-tracking methodology used in this study provided an opportunity to understand learner’s perceptual processing during learning a concept.

The results of this study indicated that too much information does not help in concept learning. At the same time, providing some learner control on display of information and providing information in smaller units help the cognitive processes involved in learning a concept. Though not statistically significant, the trend showed reduction in work overload and better performance with learner-controlled progressive display. Qualitative analysis also supports the learner satisfaction and preference for progressive presentation with learner control.
Acknowledgements

I would like to express my deepest appreciation to all those who provided me the opportunity to complete this project.

A special gratitude to my committee members, Dr. Evelyn Rozanski, Dr. Michael Yacci, and Dr. Anne Haake for their guidance, support, and continued encouragement through the entire experience. Without their guidance and persistent help this project would not have been possible.

Furthermore, I would also like to acknowledge the support I received from my friends Dong Wang and Kate Walden, who were always there to help me with the equipment, access to eye-tracking lab, and sharing their expertise in eye tracking field with me. Also, I possibly could not have brought a closure to this work without the help of my participants who took interest in my study and gave time from their busy schedules to participate in the study. Thank you all.

Finally, my education and all the work that I did during my time at RIT is a result of unending support and love from my family. My husband, mother, sister-in-law, and brothers who stood by me and always encouraged me through the tough times. My daughter who believed in her mommy and who had to grow up much sooner than she was supposed to. Last but not the least, a dream that my father left for me, he stayed by my side, lovingly guiding me through this journey.

Thank you all.

Nivedita
# Table of Contents

Chapter 1: Introduction .................................................................................................................. 1

1.1 Background ............................................................................................................................... 2

1.2 Conceptual Learning ................................................................................................................. 4

1.2.1 Component Display Theory (CDT) ....................................................................................... 4

   1.2.1.1 What are Concepts? ....................................................................................................... 5

   1.2.1.2 Why Concept Learning at Use Level? ......................................................................... 6

   1.2.1.3 Application of Component Display Theory in the Study ........................................... 6

   1.2.1.4 Use Level and Processing Time ..................................................................................... 8

   1.2.1.5 Modality of Content Delivery ....................................................................................... 8

   1.2.1.6 Why Eye-tracking? ........................................................................................................ 9

Chapter 2: Research Questions ....................................................................................................... 11

Chapter 3: Methodology .................................................................................................................. 13

   3.1 Experimental Design ............................................................................................................. 13

   3.1.1 Test Material ...................................................................................................................... 13

      3.1.1.1 Concepts .................................................................................................................... 13

      3.1.1.2 Treatment Variations of Presentation ....................................................................... 14

      3.1.1.3 Treatment/Introduction Screen .................................................................................. 16

      3.1.1.4 Questions ................................................................................................................... 16

      3.1.1.5 Flash Applications ..................................................................................................... 16

      3.1.1.6 Pilot Tests .................................................................................................................. 17
3.1.2 Content Used ........................................................................................................... 18
  3.1.2.1 Concept 1: Safe Lift .......................................................... 19
  3.1.2.2 Concept 2: Physical Signs of Lying ........................................ 22
  3.1.2.3 Concept 3: Identifying a Fraudulent Check .......................... 26
  3.1.2.4 Concept 4: Identifying a Suspicious Package ................. 30
  3.1.2.5 Concept 5: Brewing Wine .................................................. 34

3.2 Treatment Design ..................................................................................................... 39

3.3 Participants Recruitment ......................................................................................... 40
  3.3.1 Participant Demographics .................................................................................. 41

3.4 Materials and Equipment ......................................................................................... 44

3.5 Environment ............................................................................................................ 44

3.6 Procedure ................................................................................................................ 45

3.7 Eye-tracking Calibration ............................................................................................ 46

3.8 Data Collection ......................................................................................................... 47

Chapter 4: Data Analysis and Results ............................................................................. 48
  4.1 Degree of Complexity between the Concepts .......................................................... 48
  4.2 Research Question 1 ............................................................................................... 49
  4.3 Research Question 2 ............................................................................................... 51
  4.4 Research Question 3 ............................................................................................... 54
  4.5 Research Question 4 ............................................................................................... 61
  4.6 Qualitative Analysis ................................................................................................. 67

Chapter 5: Discussion ...................................................................................................... 69
  5.1 Implications on eLearning and Content Usability ................................................ 71
Attachment 6: Time on Task for each Concept with each Variation ......................................................... 99

Attachment 7: Dwell Analysis for Concepts in variations V1 to V5 ......................................................... 101

Attachment 8: Distribution of Total Time on Session ............................................................................... 103

Attachment 9: Post Session Questionnaire Responses ............................................................................. 103

Attachment 10: Calibration Error ........................................................................................................... 106
List of Figures

Figure 1: Usability Levels for Technology Supported Instructions ........................................... 1

Figure 2: Content-Performance Framework (Merrill, D., 1983 Component Display Theory) .......... 4

Figure 3: Click Here Button Before and After Pilot Tests.......................................................... 18

Figure 4: Safe Lift Variations V1 to V4 with their Examples ..................................................... 20

Figure 5 (a): Safe Lift Variation V5 ......................................................................................... 20

Figure 5 (b): Safe Lift Variation V5 Example .............................................................................. 21

Figure 6: Safe Lift Questions........................................................................................................ 21

Figure 7: Lie Detection Variations V1 to V4 with Examples .................................................... 23

Figure 8 (a): Lie Detection Variation V5 .................................................................................... 24

Figure 8 (b): Lie Detection Variation V5 Example ...................................................................... 25

Figure 9: Lie Detection Questions .............................................................................................. 26

Figure 10: Fraud Check Variations V1 to V4 with Examples ..................................................... 27

Figure 11 (a): Fraud Check Variation V5 .................................................................................... 28

Figure 11 (b): Fraud Check Variation V5 Example ...................................................................... 29

Figure 12: Fraud Check Questions............................................................................................... 30

Figure 14 (a): Suspicious Package Variation V5 ....................................................................... 32

Figure 14 (b): Suspicious Package Variation V5 Example ........................................................ 33

Figure 15: Suspicious Package Questions.................................................................................... 34

Figure 16: Brewing Wine Variations V1 to V4 with Examples .................................................... 35

Figure 17 (a): Brewing Wine Variation V5 .................................................................................. 36
Figure 17 (b): Brewing Wine Variation V5 Example ................................................................. 37
Figure 18: Wine Brewing Questions .......................................................................................... 38
Figure 19: Repeated Measure Treatment Design ...................................................................... 39
Figure 20: Participants Recruitment Details ............................................................................ 42
Figure 21: Age Distribution of Participants ............................................................................ 42
Figure 22: Experience with eLearning .................................................................................... 43
Figure 23: Discipline Distribution .......................................................................................... 44
Figure 24: Lab Environment .................................................................................................... 45
Figure 25: Box Plot of Scores Data for V1 to V4 .................................................................. 50
Figure 26: Moods Median Test Scores Vs Variations (V1 to V4) ............................................. 51
Figure 27: Box Plot of Scores Data for V1 to V4 .................................................................. 53
Figure 28: Moods Median Test Scores Vs Variations (V4 and V5) ........................................... 53
Figure 29: Example Text and Graphic AOIs .......................................................................... 55
Figure 30: Text and Graphic AOIs in V5 .............................................................................. 55
Figure 32: Total Dwell Time for Text and Graphic AOIs in V1, V2, V3, V4 .......................... 58
Figure 33: Moods Median Test for Total Dwell Time on Graphics for V2 to V4 ..................... 59
Figure 34: Revisits Count V1 to V4 ....................................................................................... 60
Figure 35: Average Time on Task (in ms) for V4 and V5 ....................................................... 62
Figure 36: Anderson Darling Test for Time on Task Data in V4 and V5 ............................... 62
Figure 37: Time on Task Histogram for V4 and V5 ............................................................... 63
Figure 38: One Way ANOVA Results for V4 and V5 ............................................................ 63
Figure 39: Number of Fixations between V4 and V5 ............................................................ 64
Figure 40: Average Fixation Durations between V4 and V5 ................................................ 65
Figure 41: One-Way ANOVA Result for Fixation Durations between V4 and V5 ........................................ 66
Figure 42: Participants’ Preferences on Variations Used ........................................................................... 67
Figure 43: Comparative Analysis between V2 and V4 ............................................................................. 69
Figure 42: Histograms for Scores C1 to C5 ............................................................................................ 94
Figure 43: Anderson Darling Test for Scores (C1 to C5) ....................................................................... 95
Figure 44: Chi-Square Test to Check Complexity between Concepts ...................................................... 95
Figure 45: Histograms for Scores V1 to V5 ............................................................................................ 96
Figure 46: Probability Plot for Scores V1 to V5 ...................................................................................... 97
Figure 47: Probability Plot for Dwell Time for Text AOI (V1 to V4) ......................................................... 97
Figure 48: Probability Plot for Revisit Count in Text AOI (V1 to V5) .................................................... 98
Figure 49: Moods Median Test for Revisit Count in Text AOI (V1 to V4) ................................................. 99
Figure 50: Box Plots of Time on Task for Concepts 1 to 5 .................................................................... 100
Figure 51: Dwell Time for Concepts 1 to 5 ............................................................................................ 102
Figure 52: Time to go Through the Session .......................................................................................... 103
Figure 53: Boxplot of Calibration Error ............................................................................................... 106
List of Tables

Table 1: Challenges Facing the Field of Instructions and Training ........................................... 2
Table 2: Matrix of Components used in the Variations Tested ..................................................... 7
Table 3: Concepts Used and Conventions Used in the Document ............................................. 14
Table 4: Treatment Variations for Presentation ............................................................................. 15
Table 5: Order of Concepts and Variation .................................................................................... 39
Table 6: Order of Participants and Sets ....................................................................................... 40
Table 7: Participant profiles ........................................................................................................ 41
Table 8: Gender and Educational Qualifications ......................................................................... 43
Table 9: Performance Scores for V1 to V4 ................................................................................. 49
Table 10: Performance Scores for V4 and V5 ............................................................................ 52
Table 11: No. of Participants and their Sequence of Visiting an AOI ......................................... 56
Table 12: Total Dwell Time (in ms) on Text and Graphic AOIs for V1, V2, V3, V4 ..................... 57
Table 13: Scores Data for Participants (Concepts) .................................................................... 93
Table 14: Variation Preference ..................................................................................................... 104
Table 15: Order of Content Preference ......................................................................................... 105
Table 16: Opinion on Effectiveness of eLearning ..................................................................... 105
Chapter 1: Introduction

The domain of instructions and training has evolved beyond the boundaries of traditional classroom settings, lectures, and books to anywhere anytime learning (mobile learning), synchronous and asynchronous online learning, gaming, simulations, and augmented reality. In the last two decades, advances in technology have completely changed the way instructors and learners look at the educational/instructional content, delivery, and accessibility. As technology is taking the front face in academia and corporate training environment, a lot of emphasis is being placed on the usability of devices and interfaces for the educational use. The devices and the software are being designed with the latest user research to ensure their ease of use, efficiency, and mobility. However, not much has been done in the study of the topmost content/instructional material layer that is intrinsically linked with the pedagogy and efficiency in knowledge transfer (Figure 1). There is a huge gap in the research of the content, its presentation, learnability, and pedagogical usability in the technology supported learning environments. There is an increasing need to advance the study of usability for this topmost layer and to research ways in which content, specific presentations, or pedagogy might have measurable impact on the specific cognitive tasks or goals.

![Usability Levels for Technology Supported Instructions](image)
1.1 Background

The challenges facing instructions and training are a result of the environmental changes that have affected learning needs and performance expectations of learner, instructors, and organizations (Table 1). While academic education is more and more geared towards developing the vocational and specialized skills, learners of the millennium generation expect content/instructional material to seamlessly integrate with their devices and the learning goals. On the other hand, in the corporate scenario, training budgets have taken severe cuts and trainees are expected to start contributing to the production within weeks after recruitment. Companies no longer allocate budgets for extensive and expensive offsite training programs or hire specialized trainers. As Bonk (2004) states, training professionals and organizations are required to keep up with new training solutions, demand for training, and significantly reduced budgets through which they are expected to deliver training/instructions resulting in higher performance at work and academics.

Table 1: Challenges Facing the Field of Instructions and Training

<table>
<thead>
<tr>
<th>Academics</th>
<th>Corporate Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>increased cost of education</td>
<td>decreased training budgets</td>
</tr>
<tr>
<td>increase in adult education</td>
<td>reduced training time</td>
</tr>
<tr>
<td>increased demand for vocational courses</td>
<td>constant increase in productivity targets</td>
</tr>
<tr>
<td>anytime anywhere education</td>
<td>increased workforce mobility</td>
</tr>
<tr>
<td>increase in specialized disciplines</td>
<td>increased complexity in work areas</td>
</tr>
<tr>
<td>changed expectations of students, instructors, and management</td>
<td>decreased hands-on-training time</td>
</tr>
<tr>
<td></td>
<td>changed expectations of learners, trainers, and management</td>
</tr>
</tbody>
</table>

To face these challenges, most professional organizations and academic institutions today are trying to find solutions using technology. They are looking for alternative training solutions that are short-term, highly specialized, relatively quick, less expensive, and effective. There is a huge requirement for the in-house training with highly targeted customized simulations and electronically delivered training material that require minimum instructor presence. Traditionally, organizations and academic institutions had been using eLearning or other forms
of technology supported learning to deliver soft-skill and hard-skill courses, such as induction training, IT training, compliance and health & safety, and so on. However, the scenario becomes somewhat complicated where higher order content such as conceptual learning is involved, especially in the highly specialized and professional environment. Here, the learner is not only required to assimilate a concept in less time but is also required to apply a concept in new situations with constrained error tolerance thresholds. A learner is expected to remember a concept as well as generalize it (use information in new scenarios). In the absence of hands-on experience and real practice sessions, learning is completely dependent on efficiency of the training material that explains and demonstrates the concept with multi-media components such as text, audio, imagery, animations, and simulations.

With this low cost and high performance matrix, there is a need to revisit our training strategies and instructional material to find ways that can reduce the learning curve and are conducive to optimal knowledge transfer. More specifically, in conceptual learning, the electronically delivered training material needs to be highly targeted, taking advantage of the medium to deliver the right amount of information in the most optimal format to facilitate cognitive processes of the learner.

This study was an attempt to investigate if there is an efficient way to present instructional content in concept learning that helps reduce the workload for the learner and results in better performance. The study also considered some measures of eye movements to investigate learners’ intrinsic response to the presentations tested in the study. These measures are used in the study to evaluate the efficiency of the presentation method with respect to the cognitive processes involved in concept learning.
1.2 Conceptual Learning

1.2.1 Component Display Theory (CDT)

In Component Display Theory, Merrill(1983) proposed a Content-Performance Framework for the learner-driven, computer based instruction. This theory classify learning in a two dimensional matrix of Content and Performance (Figure 2).

![Content-Performance Framework](image)

*Figure 2: Content-Performance Framework (Merrill, D., 1983 Component Display Theory)*

**Content Categories:** Content can be categorized as facts, concepts, procedure, and principles.

- **Facts** – Factual information such as name, place, dates, symbols or parts of an object. For example, the value of gravity constant is $9.8 \text{ m/s}^2$.

- **Concepts** – Groups of objects or events that share common attributes or characteristics and are identified by a common class. For example, attributes for living organisms could be: a finite life span, they respire and reproduce, etc.

- **Procedures** – Ordered sequence of steps necessary to achieve a goal or solve a problem. A step-by-step guide to replace a cartridge of a printer is an example of a procedure.

- **Principles** – The cause and effect or the causal relationship that can be used to interpret events or results of a process. For example, increasing the temperature causes metal to expand is a principle.
Performance Categories: Performance category tries to classify how content is used. It has Remember, Use, and Find levels. Remember is considered lowest on the cognitive value and Find at the highest.

- **Remember** level performance requires the learner to use memory to reproduce or recognize a piece of information that was previously known to him. Naming the symbol of a resistor/capacitor is a Remember level performance.

- **Use** level requires the learner to generalize or apply abstraction to a piece of information for a specific case. Determining how much resistance a circuit would need to function is a Use level performance.

- **Find** level requires that the learner apply known information to derive or invent a new abstraction. Creating a new circuitry for say, a traffic signal would be a Find level performance.

### 1.2.1.1 What are Concepts?

In their advanced instructional design guide Merrill, Tennyson, and Posey (1992) define a concept as “a set of specific attributes (objects, symbols, or events) that are grouped together on the basis of shared characteristics and that can be referenced by a particular name or symbol” (page 6). A critical attribute(s) is the necessary condition for determining if an instance belongs to a concept class. If a given instance lacks a critical attribute, it cannot be a member of the class. For example, the critical attribute that classifies a number as an even number, is its divisibility by 2. Therefore, for the concept class ‘Even Numbers’, a number that is not completely divisible by 2 (a critical attribute here) cannot belong to it.

A similar interpretation is also given by theorists of classical theory i.e. a complex concept has some necessary and jointly sufficient conditions, and for an instance to belong to that concept, it must satisfy all those conditions. In other words, for a complex concept A, there will be some individually necessary and sufficient conditions that must be satisfied by an object-instance to be classified as an occurrence of concept class A. Any or all unsatisfied conditions would mean that an object-instance cannot be classified under the concept A. Theoretically speaking, learning a concept requires the ability to correctly isolate and apply the attributes of specific
objects/instances into their correct categories. Concept learning is also intrinsically dependent on the ability to identify the examples and non-examples based on the attributes associated with that concept.

Taking the above interpretation of concepts, a learner can be presented with a concept definition that lists the critical and necessary attributes of that concept, in textual, graphical, or mixed presentation formats. In this study, we focused on Concept learning at the Use level.

1.2.1.2 Why Concept Learning at Use Level?

In concept learning, it is important to understand the level of learners’ behavior at which a concept is learned. For instance, a learner may remember the definition (or the sufficient and necessary attributes) of a concept - which would be considered at Remember level (as proposed by Component Display Theory explained in the above section), however, he/she would be considered to have learned a concept meaningfully only when he/she is able to apply or classify the un-encountered instances and non-instances of a concept. According to Merrill and Boutwell (1973), “Meaningful learning is demonstrated (and is usually required) only at the use level of student behavior (page 71).

In professional and academic fields, we rarely come across situations where concepts are applied literally. A learner is usually faced with new or slightly twisted scenarios to apply the knowledge and react or take decisions accordingly. Therefore, it becomes even more important to make sure that the concept is taught correctly and effectively to ensure that the learner is able to understand the context and react as appropriate in unfamiliar occurrences of a concept.

In this study, we applied Merrill’s Component Display Theory (1983) to design the instructional material used in testing of presentation formats and learner-controlled progressive presentation of information.

1.2.1.3 Application of Component Display Theory in the Study

Merrill (1983) suggests expository and inquisitive presentation formats as the primary presentation approach for designing content (page 306). He also suggests the secondary presentation methods that can be used to elaborate the primary presentation and facilitate information processing processes.
For the purpose of this study, we chose expository approach as the primary presentation form and Mathemagenic Help (attention focusing) as the secondary presentation form to design testing material for this study. Using expository approach, the study introduces a concept with a list of its critical attributes/definition (generality) earlier in the sequence, followed by its examples/non-examples (instances). As the secondary presentation form, elaborations with varied degree of attention focusing on graphics/illustrations such as arrows, circles, and labels were used to guide learner through the critical attributes of the concepts. As Mayer (2001) in his Cognitive Theory of Multimedia Learning suggested, we provided both text and graphics on the same screen to give the learner a better opportunity to build connections between the textual and visual information (page 57).

Using the guidelines from above two theories, the following components of content were used in creating the primary and the secondary presentation forms for the study:

- Textual Information (list of critical attributes for concepts)
- Supporting Graphic/Images
- Attention Focus (arrows, circles, and highlights) and Labels on Graphics

Table 2 provides the matrix of components used to create variations tested in this study.

Note: Progressive presentation of information in variation V5 was added as a separate test condition and is not a part of CDT.

Table 2: Matrix of Components used in the Variations Tested

<table>
<thead>
<tr>
<th>Variations</th>
<th>Textual Information</th>
<th>Graphic/Images</th>
<th>Attention Focus on Graphic/Image</th>
<th>Labels on Graphic</th>
<th>Progressive Presentation of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V2</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V3</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V4</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>V5</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
1.2.1.4 Use Level and Processing Time

Component Display Theory (1983) suggests that the type of memory involved with Concepts at Use level is Algorithmic Memory (page 301). Algorithmic Memory is a more dynamic form of memory in which information is not encoded in the same literal form as it is presented. In case of concepts, the learner creates a cognitive schema with information; concept definition/attributes, examples, and non-examples. This schema works as a framework with variables for attributes of a concept. As learner comes across a new instant he actively processes this schema to compare variables of that instance with the variables in his schema and then classify that instance as a member or a non-member of that class. In other words, the learner uses a schema to process new input and make decisions. This active cognitive processing requires moderate amount of time.

Considering active processing involved in concept learning and giving room to individual reading styles and speeds, this study kept the time factor open. Participants were given control in terms of time they required in processing the information on screen and moving to the next screen. However, to control the integrity of learning measures used in the study, participants were not provided with Back button. Therefore, participants could not go back to the previous content screen. Additionally, design of the test material ensured that all participants answered all the questions used for performance measure before moving to the next concept.

1.2.1.5 Modality of Content Delivery

Component Display Theory (1983) gives a clear and logical explanation on the content, its components, and presentation. However, Merrill does not provide any clear guidance on use of modality for the delivery of this content. There is no discussion in Component Display Theory about the auditory, visual, or tactile channels that might have an effect on concept learning.

In The Cognitive Theory of Multimedia Learning (2001), Mayer suggests that meaningful learning involves cognitive processing to create logical constructs/connections using information presented by visual/pictorial and auditory/verbal information. This theory also suggests that when presented with both visual/pictorial and auditory/verbal information, humans have limited capacity to process information from each of these channels. To avoid this conflict in learning results from multiple channels, we decided to test Component Display Theory using visual/pictorial modality only in the study.
1.2.1.6 Why Eye-tracking?

Studying eye-movements is a unique way to understand the visual processes involved in attention and the areas or aspects of visual information that are most effective in contributing to cognition and information processing. Eye tracking is used as an effective tool in the fields of psychology, cognitive sciences, and HCI. However, it has not been much utilized in the field of instructional technology. There are very few studies done using eye tracking in the instructional and training domain to understand how a learner’s interaction with visual content and its presentation strategy might produce different results in the learning process. In his paper Mayer (2010), discusses the results of six eye-tracking studies done by various researchers on eye tracking as a tool to study and enhance multimedia learning. He discusses eye movement behaviors to bring focus to the need of consistency in designing learning environments using graphics with the principles of how people learn. However, there still is a huge gap in our knowledge about what eye tracking can tell us about designing instructional material.

Our eye movements are guided by our attention and this coupling of eye movements and attention can provide us with insights on the effect of visual information on human cognitive processing. When interacting with visual mediums, human eyes gather information with sequences of fixations on specific areas and fast movements between the areas (saccades). Fixations occur when the eye rest on a spatial location, typically over a minimum duration of 100-200 ms (Jacob & Karn, 2003). While cognitive processing of the information is said to occur between fixations, saccades can be a good indicator of the pattern in eye movements from one area of interest to another. Monitoring these sequences of fixations and saccades during interactions with the learning/information material can give us some insight to the cognitive processes taking place in the learner’s mind.

As Yarbus (1967) concluded that eyes are involuntarily directed to the areas that are most informative or useful to perception, in learning and instruction learner’s attention is guided by the informative value of the content presented. Mackworth and Morandi (1967) further corroborated that human eye is most likely to fixate on the most informative region within first few second of viewing. In context of concept learning using electronic medium of delivery, these findings can have a huge implication to the design of learning material. Just and Carpenter (1980) in their study of eye fixations and comprehension found that there is an intrinsic positive
relationship between the amount of time eyes fixated on an informative region and the level of difficulty in its comprehension. Thus, higher fixation durations can be an indicator of difficulty in comprehension. Eye-tracking data of the learner’s interactions on the screen can give us information about her behavior with the stimulus and consequently indicate the effectiveness of that stimulus.

This study used simple eye-tracking measures such as fixation frequency and durations, revisits, and dwell time to investigate learner’s interactions with predefined variations in visual stimulus and comparing performance with respect to each stimulus. Based on the work of Mayer (2001), we also saw a possibility of cognitive overload with the over-use of certain information and therefore decided to use eye tracking to understand the aspects of visual processing and cognition associated with the components (textual information, graphical information, attention focusing) used in designing this study.
Chapter 2: Research Questions

Visual attention is considered as a directed action by brain to prioritize and identify specific areas of information that are conducive to fast and relevant information processing. Eyes are considered to direct the attention and it is said that a person’s attention is where his eyes are looking (Christianson et al. 1991). Researchers call it eye-mind hypothesis, which states that there is a close link between the direction of gaze and the focus of attention. There are some studies on how people process information in text and graphical forms. In the field of digital reading devices, the study on textual information has shown that people tend to pay more attention to the areas that are highlighted (VonRestorff, 1933). Chi et.al (2007) conducted an eye-tracking study to provide evidence of Von Restorff isolation effect for highlighting interfaces. Their study suggests that a reader’s attention is directed to the highlighted areas, regardless of their appropriateness to the task. They found that there is a direct correlation between different highlight conditions (no highlighting, keyword highlighting, and sentence highlighting) in the text and the user’s visual foraging behavior. (Chi, Ed.H, Gumbrecht. M, and Hong .L, 2007). A parallel argument to their hypothesis would be if context of task at hand directs the focus of attention. Thus, a subject attending to a particular task is more likely to be moving his eyes on the focus areas if they are relevant to the task. In early 1973, Kanheman (Kanheman .D, 1973) argued that in free-viewing tasks, subjects that are given no instructions behave in the same way as the subjects who are told to look at specific areas. Kanheman suggested that eyes are unconsciously directed to the areas that are more informative. However, Kanheman’s theory needs to be seen within the context of the task especially where the cognitive processes are involved. As Generative Learning Theory (Wittrock MC, 1974) suggests, learner participates actively seeks information to construct meaningful understanding of information from the environment. This becomes even more important in the technology supported learning environment, where the learner is interacting with the environment and the content through the layer of technology. In this case, the instructional material needs to take advantage of the media to support cognitive processes of the learner. Also, since technology enables multiple modes of content presentation, it can be used to deliver a lot of information in different formats. However, this also raises the question if there is an optimal amount of information that can facilitate
efficient learning process? How much highlighting/attention-focus is good or is required for effective assimilation of information? In the light of what multi-media can make possible, what are the presentation strategies that might contribute most to cognition process?

To investigate the above-mentioned areas, this study focused around how different learners make use of the presented visual stimuli to learn a concept. We tried to find answers to the following questions though this experimental study:

- **Question 1**: What combination of text, graphics, and annotations is most effective in learning to generalize the concepts?
- **Question 2**: Does learner-controlled progressive presentation of information has any affect on learning?
- **Question 3**: How do learners behave with text and graphical informative areas when assimilating the information required in learning to generalize a concept?
- **Question 4**: How does learner-controlled progressive presentation of information change learner’s interaction with the content?

The objective of investigating these questions was to:

- Investigate if there is an optimal amount of information that works best for the cognitive processes involved in concept learning
- Explore learner behavior with text and graphical information and look at possible design implications based on this behavior for effective instructional strategies in technology supported learning environments
Chapter 3: Methodology

3.1 Experimental Design

3.1.1 Test Material

To investigate the research questions in this study, testing material was developed with guidance from Merrill’s Component Display Theory and Mayer’s Theory of Multimedia Learning. The following components were used to create the testing material.

1. Five selected concepts
2. Five selected presentation variations to present the selected concepts
3. Four questions for each concept as performance measure of learning
4. Five sets of applications created with Flash/AS3 each with a different order of concepts and variations

Following sections describe each of these components.

3.1.1.1 Concepts

Five concepts (Table 3) of fairly equal complexity were selected. To eliminate the influence of prior content knowledge, concepts were carefully chosen from the areas that were expected not to be known to the general population of students (intended participants for the study) and were not discipline specific. Instructional content for the selected concepts was developed using textual information, graphics, annotations, labels, and directions. Each concept was followed by its examples and non-examples to help participants create a mental framework of variables for that concept.

Table 3 lists the selected concepts and their convention used in this document. The concepts and their attributes are described later in this chapter.
Table 3: Concepts Used and Conventions Used in the Document

<table>
<thead>
<tr>
<th>Concepts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept 1</td>
<td>C1</td>
</tr>
<tr>
<td>Concept 2</td>
<td>C2</td>
</tr>
<tr>
<td>Concept 3</td>
<td>C3</td>
</tr>
<tr>
<td>Concept 4</td>
<td>C4</td>
</tr>
<tr>
<td>Concept 5</td>
<td>C5</td>
</tr>
</tbody>
</table>

3.1.1.2 Treatment Variations of Presentation

Five variations (Table 4) with different combinations of text, graphics, and annotations (attention focus and labels) were identified. Each concept was developed with the five variations listed in Table 4.

- Variation 1: This variation presented concept attributes in textual format. There were no supporting image or illustrations provided for this variation.
- Variation 2: This variation presented concept attributes in textual format with a supporting image/graphic displayed to the right of the text. There were no annotations or attention focusing on the image.
- Variation 3: This variation presented concept attributes in textual format with a supporting partially annotated image/graphic. The annotations were in form of attention focus using only arrows and circles on the relevant areas of the image. The image with partial annotations was displayed to the right of the text.
- Variation 4: This variation presented concept attributes in textual format with a supporting completely annotated image/graphic. The annotations were in form of attention focus (arrows and circles) and complete labels on the relevant areas of the image. The image with complete annotations was displayed to the right of the text.
- Variation 5: This variation presented concept attributes in textual format with a supporting completely annotated image/graphic as in variation 4. However, in this variation the learner was given the control to display one attribute at a time with its textual and the relevant annotated area on the image simultaneously. The learner in this case received information progressively and in smaller units. This variation was not a part of Component Display Theory.
Table 4: Treatment Variations for Presentation

<table>
<thead>
<tr>
<th>Variations</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation 1</td>
<td>Textual Information Only</td>
<td>Textual Information + Graphics with no annotations</td>
<td>Textual Information + Graphics with partial annotations</td>
<td>Textual Information + Graphics with complete annotations</td>
<td>Textual Information + Graphics with complete annotations + Progressive disclosure under User control</td>
</tr>
</tbody>
</table>

Note:

- Partial Annotations refers to attention focusing using arrows and circles on the graphics.
- Complete Annotations refers to attention focusing using arrows, circles, and labels on the graphics.
- Progressive disclosure refers to step-by-step display of information on the screen with learner control on the pace of the display.
- In all the variations the textual information was placed on the left side of the screen and the images/illustrations with their annotations were located on the right side of the same screen.
- The labels used on the graphics were considered as graphic elements and not treated as textual information.

**Placement of Text and Graphics**

According to Mayer’s spatial contiguity principle (Mayer, 2001), learners are better able to mentally integrate corresponding words and graphics if they are presented on the same screen. Having text and graphics on the same screen helps learners to use their cognitive resources to build connections rather than going back and forth between words and graphics. Therefore, integrated presentation (text and graphic on the same screen at the same time) with text on the left and graphics on the right was used in variations that provided graphics (V2 to V5).
3.1.1.3 Treatment/Introduction Screen

Each concept was introduced on the first slide using one of the presentation variations listed above. The content presentation method used on this screen acted as the stimulus for learning. Learner could control how much time he needed to process the information on this screen and then move to the next one.

Example Screen

To reinforce the learning from stimulus screen and following the instructional method prescribed by CDT, an example screen followed each introduction screen. The examples were presented using the same presentation variation that was used for introducing the concept in stimulus screen. Therefore, for variation 1, the example was also described in textual format.

3.1.1.4 Questions

To measure the learning after concept introduction and examples, four questions were presented to the learner for each concept. Questions were created to measure Use level learning. Since, content for the five concepts was treated visually, questions were also created using the visual stimulus. Therefore, participants were presented with four visual questions where they had to identify if the presented visual belonged to that concept class or not. Participants were not given the control to skip any of the questions.

Each question was weighted 1 point for the correct answer and no points were given for an incorrect answer. Therefore, for each concept a participant could secure a maximum 4 points for four correct answers. Participants’ responses were captured through the script written using AS3 running at the backend of the Flash application.

3.1.1.5 Flash Applications

Five sets of applications were created using Flash CS5 and Action Script 3 to deliver the developed content in electronic format. Each set had a different order of concept and its variation. Each participant went through one of these sets in the order of their participation in the study. Table 5 lists the five sets used in the study with their order of concepts and variations.
Design Specifications used in Flash Application

• Flash applications were created with the canvas size of 1180 X 780 pixels to replicate full size browser window.

• The screen design was kept simplistic with minimal use of colors to avoid influence of colors on eye movements. Background was kept neutral gray with contrasting lighter color font.

• Arial font size 25 was used for the textual content and Arial font size 30 was used for the titles and directive content.

• Red and green colors were used to mark the graphics to draw learner attention and white color font was used to label the relevant areas on the graphics.

• Content on each screen appeared simultaneously (with exception to variation 5) with textual information on the left side of the screen and graphics, annotations, and labels on the right side of the screen.

• Minimal instructions were used where needed. Simple built-in Flash buttons were used for questions (radio buttons) and for navigation from screen to screen.

• Back button was not provided to prevent learners from going back to look at the attributes while answering the questions.

• The Next button in each question screen was enabled only after participant had answered that question. This was done to prevent participants skipping questions.

3.1.1.6 Pilot Tests

Two pilots were conducted before running participants for the study. Participants for the pilot study were selected from the pool of interested participants.

Following changes were made to the test material after running the pilots:

• Text and background contrast was increased for better readability.

• Directive instructions were edited for clarity.

• Printed screen shots of the variations were created as a reference document for the post-session questionnaire.
• **Click Here** button used in Variation 5 was made more prominent and interactive to attract user attention.

![What signs indicate that a check might be fake?](image1)

**Figure 3: Click Here Button Before and After Pilot Tests**

### 3.1.2 Content Used

The following sections describe each of the concepts used in the study with their components.
3.1.2.1 Concept 1: Safe Lift

Attributes

A lift can be classified as Safe Lift if the person lifting a load demonstrates the following:

- keeps a firm footing on the ground all the time
- bends on the knees and keeps her back straight all the time
- keeps her line of sight clear all the time
- holds the load using both hands with a good grasp on it

Variations and Examples Used
Figure 4: Safe Lift Variations V1 to V4 with their Examples

Figure 5 (a): Safe Lift Variation V5
Figure 5 (b): Safe Lift Variation V5 Example

Questions

Figure 6: Safe Lift Questions
3.1.2.2 Concept 2: Physical Signs of Lying

**Attributes**

A person who is lying will show the following physical signs:

- The eyes move up and usually to their right signifying that the person is constructing a picture in his head
- Eyebrows rise towards the center of the forehead as a subtle sign of fear
- Lips are turn down and are usually tightly shut
- An accompanied hand movement, usually touching some part of the face
Variations and Examples Used

**How to detect if a person is lying?**

A person will show the following physical signs when lying:

- Eyes move up, usually to the right signifying that the person is constructing a picture in his head.
- Eyebrows rise towards the center of the forehead as a subtle sign of fear or tension.
- Lips are tightly shut and usually turned down.
- An accompanied hand movement, usually touching some part of the face.

Remember, a person who is lying will show all four physical signs listed above.

**Lie Detection: Example 1**

As Christie is telling the sequence of events from her recent visit to Paris, her eyes are looking up in the right directions, she is resting her chin on her hand, but her eyebrows are pleasantly arched and lips are smiling. She is probably trying to remember the events from her visit and not lying about them.

6 year old Myers is writing a story for her baby brother. As she actively imagines the characters to the story, her starts looking up in the left directions, she unconsciously puts the pencil in her mouth with lips apart and arches her eyebrows wide.

**Lie Detection: Example 2**

Though the person on the right has her eyes looking up in the right hand side direction, and hand in on her face too, but her eyebrows are not relaxed and lips are smiling.

She is not showing all signs of lying.

The person here is looking up in the right direction, his eyebrows are tensed, lips are tightly shut and bending down, his hand is uneasy on his neck.

This person is demonstrating all the signs of lying.

**Lie Detection: Example 3**

As Christie learns the sequence of events from her recent visit to Paris, she remaining the following physical gestures:

- Her eyes are looking up in the right direction.
- Her hand is on her face.
- Her face is pleasantly relaxed.
- Her lips are smiling.

She is probably trying to remember the events from her visit and not lying about them.

Jake is interrogating a suspect for a theft in the office. As he observes the following signs:

- The person is looking up in the right direction.
- His eyebrows are tensed.
- His eyes are tightly shut and are arched down.
- His hands are uneasy on his neck.

Jake is happy that this person should be investigate further since he is demonstrating all the signs of lying.

**Lie Detection: Example 4**

This person on the right is not showing all signs of lying.

- Her eyebrows are not raised or tensed.
- The eyes are looking up towards right.
- Her hand is on her face.
- Lips are smiling

This person is demonstrating all the signs of lying.

- His lips are tightly shut and bending down.
- His eyes are raised and tensed.
- His eyebrows are raised and tensed.
- Lips are tightly shut and bending down.
- His hand is uneasy on his neck.

---

Figure 7: Lie Detection Variations V1 to V4 with Examples
Figure 8 (a): Lie Detection Variation V5
Figure 8 (b): Lie Detection Variation V5 Example
3.1.2.3 Concept 3: Identifying a Fraudulent Check

Attributes

The following are the signs of an altered or fake check. An authentic check must not show any of the following attributes:

• Valid customer’s and bank’s addresses
• Customer’s authorized signature
• No stains or overwriting. Stains, overwriting, or discoloration on the check might indicate erasures or alterations
• MICR encoding at the bottom matching with the check number
Variations and Examples Used

Figure 10: Fraud Check Variations V1 to V4 with Examples
Figure 11 (a): Fraud Check Variation V5
Figure 11 (b): Fraud Check Variation V5 Example
3.1.2.4 Concept 4: Identifying a Suspicious Package

Attributes

The following are the characteristics of a suspicious postal package:

- Irregular shape, bulgy, or is heavy for its size
- Protruding wires, stains, buzzing or ticking sound, or strange odors
- Not addressed to a person or restrictive marking such as fragile, confidential, do not delay, or personal
- No return address or postmark not matching the city of the return address
Variations and Examples Used

Figure 13: Suspicious Package Variations V1 to V4 with Examples
Figure 14 (a): Suspicious Package Variation V5
Figure 14 (b): Suspicious Package Variation V5 Example
3.1.2.5 Concept 5: Brewing Wine

Attributes

The following signs indicate that the wine is ready for bottling and consumption:

- The wine is free of any residual CO2 gas. There should be no foam or bubbles in the liquid.
- The liquid is completely clear and transparent. There should be no or traces of yeast that needs to fall out.
- The gravity hydrometer should read less than 0.98. This reading indicates that the wine brewing process has finished.
Variations and Examples Used

**Figure 16: Brewing Wine Variations V1 to V4 with Examples**
Figure 17 (a): Brewing Wine Variation V5
Figure 17 (b): Brewing Wine Variation V5 Example
Questions

Figure 18: Wine Brewing Questions
3.2 Treatment Design

A repeated measures design was used in which each participant experienced all the five treatment variations and all five concepts as explained in Figure 19. To eliminate the influence of order of presentation, concepts and their variations were counterbalanced into five sets with each set presenting content in different order of concepts and variations.

Table 5 lists the five sets with the order of concepts (C1 to C5) and variations (V1 to V5) used.

Table 5: Order of Concepts and Variation

<table>
<thead>
<tr>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4</th>
<th>Set 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1V1</td>
<td>C3V2</td>
<td>C5V3</td>
<td>C2V4</td>
<td>C4V5</td>
</tr>
<tr>
<td>C2V2</td>
<td>C4V3</td>
<td>C1V4</td>
<td>C3V5</td>
<td>C5V1</td>
</tr>
<tr>
<td>C3V3</td>
<td>C5V4</td>
<td>C2V5</td>
<td>C4V1</td>
<td>C1V2</td>
</tr>
<tr>
<td>C4V4</td>
<td>C1V5</td>
<td>C3V1</td>
<td>C5V2</td>
<td>C2V3</td>
</tr>
<tr>
<td>C5V5</td>
<td>C2V1</td>
<td>C4V2</td>
<td>C1V3</td>
<td>C3V4</td>
</tr>
</tbody>
</table>

Where, C = Concept and V=Variation

Figure 19: Repeated Measure Treatment Design
Each participant was tested using one of the five sets in the order of their participation in the study (Table 6). Therefore, each set was tested with five participants.

Table 6: Order of Participants and Sets

<table>
<thead>
<tr>
<th>Sets</th>
<th>Participants</th>
<th>Participants</th>
<th>Participants</th>
<th>Participants</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td>Participant 1</td>
<td>Participant 6</td>
<td>Participant 11</td>
<td>Participant 16</td>
<td>Participant 21</td>
</tr>
<tr>
<td>Set 2</td>
<td>Participant 2</td>
<td>Participant 7</td>
<td>Participant 12</td>
<td>Participant 17</td>
<td>Participant 22</td>
</tr>
<tr>
<td>Set 3</td>
<td>Participant 3</td>
<td>Participant 8</td>
<td>Participant 13</td>
<td>Participant 18</td>
<td>Participant 23</td>
</tr>
<tr>
<td>Set 4</td>
<td>Participant 4</td>
<td>Participant 9</td>
<td>Participant 14</td>
<td>Participant 19</td>
<td>Participant 24</td>
</tr>
<tr>
<td>Set 5</td>
<td>Participant 5</td>
<td>Participant 10</td>
<td>Participant 15</td>
<td>Participant 20</td>
<td>Participant 25</td>
</tr>
</tbody>
</table>

To summarize, the study:

- presented five concepts as visual stimulus to the participants in pre-identified presentation formats
- recorded participant’s performance data for each of the concept and variation combination
- recorded participant’s eye-tracking data for each concept and variation combination

3.3 Participants Recruitment

Participants for the study were recruited from Rochester Institute of Technology campus and Monroe Community College, Rochester, NY. They were under-graduate and graduate students from various majors and disciplines. Participants were screened for specific characteristics (Table 7) to ensure they met the following requirements:

- Age 18 to 35
- General knowledge of and experience with the computers
- Intermediate to advance proficiency in reading and writing in English
- Minimum high school passed
Table 7: Participant profiles

<table>
<thead>
<tr>
<th>Generic Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-18 to 35 years</td>
</tr>
<tr>
<td>Education</td>
<td>High school minimum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevant Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Use</td>
<td>Moderate to high proficiency</td>
</tr>
<tr>
<td>Proficiency in English</td>
<td>Intermediate to advance proficiency</td>
</tr>
<tr>
<td>Experience with eLearning</td>
<td>Little or no experience</td>
</tr>
<tr>
<td>Professional experience as a bank teller, wine maker, courier service</td>
<td>None</td>
</tr>
</tbody>
</table>

Twenty-seven participants were recruited for the study from the student population at Rochester Institute of Technology (RIT) and Monroe Community College (MCC) in Rochester, New York. Recruitment flyers (Appendix B: Attachment 1) inviting participant involvement were posted around RIT campus. Researcher also invited study participant through her personal network of friends and colleagues at RIT and MCC. The interested participants were approached through email for further screening (Appendix B: Attachment 2). The selected participants were then invited for the study sessions at the Eye-tracking Lab at College of Imaging Science, RIT.

3.3.1 Participant Demographics

Participants were recruited between February 2013 and March 2013. Out of 33 people that responded to the recruitment posters and through researcher’s personal network, 27 including two pilots were screened, successfully recruited and completed the study (Figure 20). Three respondents did not show up on the appointed dates for the test session, two respondents cancelled ahead of the session, and one respondent responded after researcher had finished running all the 27 participants. This respondent was informed about the closure of the study and thanked for her interest in it.
Age Distribution

Two participants were between the ages of “18 and 21” years. Fifteen participants were between the ages of “22 and 25”, six were between “26 and 30” years, and two participants were between the ages of “31 and 35” years. There were no participants younger than eighteen or older than thirty-five. None of the participants indicated need of assistive services to participate in the study. Figure 21 gives the age distribution details of the participants in the study.

Gender and Educational Qualification

Of the 25 participants, 17 were males and 8 were female students. 17 participants were graduate students and the remaining 8 were undergraduate students (Table 8).
Table 8: Gender and Educational Qualifications

<table>
<thead>
<tr>
<th>Number of Participants</th>
<th>Gender</th>
<th>Educational Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>8</td>
</tr>
</tbody>
</table>

**Experience with eLearning**

The participants for this study were not required to have taken eLearning courses. For the purpose of this study, participants who had taken 1 to 3 eLearning courses sometime in their academic or professional careers were considered to have moderate experience with eLearning, and those who had taken 4 or more eLearning courses were considered to have good experience with eLearning.

12 of 25 (48%) participants did not have any prior experience with eLearning, 10 of 25 participants (40%) participants had moderate experience with eLearning, and 3 of 25 (12%) had good experience with eLearning (Figure 22).
Discipline Profile

Selected participants came from diverse academic disciplines and backgrounds (Figure 23). 7 of 25 (28%) of participants were from Engineering (Electrical, Mechanical, Industrial, and Telecommunication Engineering). 4 of 25 (16%) participants were from Information Technology, 3 of 25 (12%) were from Computer Science, 2 of 25 (8%) were from Communications, 2 of 25 (8%) from Biomedical Science, and 2 of 25 (8%) from Media Arts, and 1 of 25 (4%) from Music and Psychology each.

![Discipline Distribution](image)

Figure 23: Discipline Distribution

3.4 Materials and Equipment

The SMI Remote Eye-tracking Device (RED) System (iViewX and Experiment Center) was used to run the study and collect eye-tracking data. Participants viewed the video on a separate 17” TFT monitor. Resolution of the monitor was set to standard 1280 x 1024 pixels. The tracker was set at the frame rate of 250 Hz with filter depth of 80ms, and saccade length of 20 pixel. Participants sat at a distance of approximately 65 cm– 70 cm from the display monitor that provided the stimulus.

3.5 Environment

The Multi-Disciplinary Eye-tracking Lab located at College of Imaging Science at Rochester Institute of Technology in Rochester, New York was used to conduct the study sessions. The lab is equipped with an SMI remote eye tracker with a 17 inch TFT test monitor and an observation monitor. Participants were seated with as much comfort as possible. The door of the lab was shut
during the experiment to cut out distractions from the outdoor environment. Moderator (researcher in this case) was present with the participants all through the session.

![Lab Environment](image)

*Figure 24: Lab Environment*

### 3.6 Procedure

On the day of the appointed session, participants were made comfortable and were briefed with general information about the setup and procedure followed during the test session. They were also informed that they will be going through some content in five sections and will be required to answer four questions in each of the sections. Moderator (researcher in this case) read the test script informing participants about the duration of experiment, their rights, and personal data non-disclosure statement (Appendix B: Attachment 3). Participants were then invited to sign the consent form (Appendix B: Attachment 4) and to provide some background information (Appendix B: Attachment 5) before beginning the experiment.

After signing the consent form, participants were requested to sit at the chair provided for eye tracker machine. The chair was adjusted to accommodate the correct distance from the tracker monitor (17 to 22 inch approximately) and comfort of the participant. Participants were briefed about the calibration process and were then subjected to a 5-point calibration procedure. Calibration process was repeated in the cases where a good calibration was not achieved in the first attempt. Participants were then given the mouse control and instructed to begin interacting with the Flash application.
No practice material was provided to warm up the participants. The general instructions about the application were given at the beginning of the session and specific instructions and directions (if required) were provided on the relevant screen.

Depending on the order of their participation in the study, each participant was subjected to one of the five sets created as a Flash application. Each of the concepts was presented with:

- One treatment slide with concept introduction
- One slide with the examples of that concept
- Four question slides on that concept

Participants were given freedom to take as much or as little time as they wanted to go through the entire material. However, they were not given the control to skip any of the questions. They were not restricted from speaking out aloud during the experiment but were requested to limit their body/head movements.

After finishing the eye-tracking session, participants were requested to leave the Flash application as is on the screen and were requested to sit on a different chair. They were then handed a post-session questionnaire. At this point, moderator helped participants with general information about eye-tracking or the experiment, if they had any queries.

Finally, participants were thanked for their time and participation in study with Java’s coffee coupon and some cookies.

Note: IRB approval for running human subjects was taken prior to starting the experiment.

### 3.7 Eye-tracking Calibration

Participants were briefed about the calibration procedure before conducting the calibration. They were helped to maintain a distance of approximately 65-70 cm from screen to ensure eye tracker gets proper coverage of their eyes. Each participant went through calibration process before beginning with the test material.

The calibration process was set with 5-point calibration for RED at 250 Hz sample rate, filter depth of 80 ms, and saccade length of 20 pixels. All the subjects were calibrated on the SMI eye tracker system with a gray background. Gray background color was specifically chosen to
eliminate any kind of pupil changes due to colored background. Calibration was succeeded by additional validation procedure to ensure authenticity to the calibration. Against the accepted calibration error of 0.5, the average calibration error for the 25 participants in this study came out to be 0.6 with standard deviation of 0.33 and 0.28 for X and Y values respectively (Appendix C: Attachment 10).

3.8 Data Collection

Data for the 25 experiments was collected at three levels:

1. Performance Data: measure of efficiency in learning concepts with respect to the presentation variations. Each concept was followed by four questions and each question weighted 1 point for the correct answer. Therefore, each participant went through 20 questions in all with maximum 4 points for each concept. This data was captured using Action Script 3 on Flash CS5 application.

2. Eye-tracking Data: measure of learner behavior with presentation variations. The eye-tracking data for each participant was collected using the SMI-Experiment Center 3.2.

3. Qualitative Data: measure of preferences, opinions, and perceptions. This data was collected using background questions and post-session questionnaire.
Chapter 4: Data Analysis and Results

4.1 Degree of Complexity between the Concepts

To measure the effect of selected variations on learning, it was important that the concepts used were of the same complexity level and were in no way an influencing factor on performance. To avoid any outside influence on data, the following considerations were used to select them for the study:

• to avoid influence of prior knowledge, concepts had to be generic and not discipline specific
• since we were testing visual/pictorial modality in the study, selected concepts had to be visually explainable
• each participant was subjected to each of the five chosen concepts to nullify any effect of complexity between the concepts

However, to further investigate if any of the concepts was unusually complex or simple and consequently resulting in lower or higher scores respectively, the performance scores for the five concepts were put through the Chi-Square test (Appendix C: Attachment1). P-value for Chi-Square test came out to be 0.263, which is very high and therefore we failed to find any evidence of statistically different performance in any of the five concepts. Hence, the test determined that complexity of concepts was not the influencing factor in the performance of participants.

Thus for the analysis, complexity of the concepts was considered equal and not an influencing factor on the data.
4.2 Research Question 1

What combination of text, graphics, and annotations (attention focus and labels) is most effective in learning to generalize concepts?

**Measure:** Performance scores of participants on each combination of text, graphics, and annotations in treatment variations V1, V2, V3, and V4

**Data:** To investigate if a combination of text, graphics, and annotations (attention focus and labels) was most effective in learning concepts, performance data for variations V1 to V4 was used in the analyses. Table 9 lists the scores that 25 participants scored on five concepts presented in four different variations (V1 to V4).

*Table 9: Performance Scores for V1 to V4*

<table>
<thead>
<tr>
<th>Participant</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>P2</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>P3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>P4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>P5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>P6</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>P7</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>P8</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>P9</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>P10</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>P11</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>P12</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>P13</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>P14</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>P15</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>P16</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>P17</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>P18</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>P19</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>P20</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>P21</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>P22</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>P23</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>P24</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>P25</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Total Score</td>
<td>75</td>
<td>83</td>
<td>78</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>
Observations

Participants’ score data indicate that participants performed best in V2; V4 on the other hand, resulted in worst performance. To check if there really was any significant difference in the scores for these variations (V1, V2, V3, and V4), we performed the following statistical tests on this data.

1. Normalcy Test: Anderson Darling test on the performance data for variations revealed that it is non-normal. Additionally, histograms of the score data for each variation (V1 to V4) supported non-normalcy of data. Please see Appendix C: Attachment 2 for details.

2. Box-Plot: Box-plots (Figure 25) also indicate different means and medians (except in V1) for variations and existence of outliers.

![Boxplot of Scores Across Variations V1 to V4](image)

*Figure 25: Box Plot of Scores Data for V1 to V4*

3. Moods Median Test: Since the performance data came out to be non-normal and with presence of outliers, Moods Median test was chosen to test the statistical difference in the performances for variations V1 to V4 (Figure 26).
The P-value for this test came to be 0.373, which is very high and we failed to find any significant difference in the performance for variations 1 to 4 (V1 to V4).

**Analysis**

The results of Moods Median test indicate that participants did not perform particularly better or worse in any of the combinations of text, graphics, and annotations (attention focus and label). And, therefore we cannot say that there was a combination that contributed best to learning to generalize concepts. Although the scores are not statistically significant, boxplot reveals that the average scores were best in variation V2 and least in V4. It also indicates that between the tested variations, V4 has the highest variation in scores. This result presented an opportunity to look at these variations more closely in relation with learner behavior and is discussed later in this document.

### 4.3 Research Question 2

**Does learner-controlled progressive presentation of information has any affect on learning?**

**Measure:** Performance scores of participants in variations V4 and V5

**Data:** Variations V4 and V5 presented an interesting case where both these variations presented most complete information using text and graphics with complete annotations (attention focus and labeling). However, in contrast to upfront display of complete information in V4, V5 presented information progressively with learner’s control on the pace of display. Table 10 below lists the scores that 25 participants scored on the five concepts for variations V4 and V5.
Table 10: Performance Scores for V4 and V5

<table>
<thead>
<tr>
<th>Participant</th>
<th>V4</th>
<th>V5</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>P2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>P3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>P5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>P6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>P7</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>P8</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>P9</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P10</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>P11</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>P12</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>P13</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>P14</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>P15</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>P16</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P17</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P18</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>P19</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>P20</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>P21</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P22</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>P23</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P24</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>P25</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total Score</td>
<td>71</td>
<td>81</td>
</tr>
</tbody>
</table>

Observations

1. Normalcy Test: Anderson Darling test on the performance data of V4 and V5 revealed that it is non-normal. Additionally, histograms of the score data for each variation (V4 and V5) supported non-normalcy of data. Please see Appendix C: Attachment 2 for details.

2. Box-Plot: Box-plots (Figure 27) also indicate different means and medians in both V4 and V5 and existence of outliers.
3. Moods Median test was applied on the scores for V4 and V5 to test if there was any significant difference between them (Figure 28).

**Mood Median Test: Scores versus Variation for (V4 and V5)**

Mood median test for Scores (V4 and V5)
Chi-Square = 3.00, DF = 1, P = 0.083

<table>
<thead>
<tr>
<th>Variation</th>
<th>N&lt;=</th>
<th>N&gt;</th>
<th>Median</th>
<th>Q3-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>V4</td>
<td>18</td>
<td>7</td>
<td>3.00</td>
<td>2.00</td>
</tr>
<tr>
<td>V5</td>
<td>12</td>
<td>13</td>
<td>4.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Individual 95.0% CIs

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00</td>
<td>3.30</td>
<td>3.60</td>
<td>3.90</td>
</tr>
</tbody>
</table>

Overall median = 3.00

A 95.0% CI for median(V4) - median(V5): (-1.00, 0.00)

**Figure 28: Moods Median Test Scores Vs Variations (V4 and V5)**

P-value for scores for variations V4 and V5 is 0.083, which is greater than 0.05 and thus not statistically significant.
Analysis
Although, we found P-value not indicative of any significant difference between the scores for V4 and V5, but it is very close to 0.05 and suggests that there might be a possibility that progressive presentation with learner control on pace in V5 have some influence on the better performance in V5 in comparison to V4. Boxplots also reveal that both mean and median scores in V5 are higher than in V4. Also, the variation in scores for V5 is much less than in V4, indicating more consistent performance by participants in V5.

4.4 Research Question 3
How do learners behave with text and graphical informative areas when assimilating the information required in learning to generalize a concept?

Measure: The other questions that this research study was interested to investigate were concerned with learners’ interactions with the informative areas on screen. We were interested to understand how text and graphic components contributed to the cognitive processes involved in learning. To explore learner’s behavior with the text and graphics areas the following measures were used:

- Measure 1: area that attracts learner’s attention first
- Measure 2: time learners spend on each of these areas
- Measure 3: how many times do learners need to revisit these areas to assimilate information

To evaluate these measures, the content screens for each concept was divided into two separate areas: text area and graphics area. In eye-tracking terminology, these areas were defined as the Areas of Interest (AOI). Areas of interest are the regions that are specified over a field of view and that indicate specific sources of information within that field. Areas of interest are usually defined for specific tasks or activities that are expected to take place within specific areas on the field of view (Jacob & Karn, 2003).

Areas of Interest (AOIs) on each of the content screens were created using SMI-BeGaze 3.2 as shown in the example Figure 29 and Figure 30.
Measure 1: area (AOI) that attracts learner’s attention first

Data: The data for the two AOIs was collected using BeGaze analysis tools. Table 11 shows the number of participants who visited text AOI first and the participants who visited graphic AOI first as they entered the screen on each of the variations.
Table 11: No. of Participants and their Sequence of Visiting an AOI

<table>
<thead>
<tr>
<th></th>
<th>Text AOI</th>
<th>Graphic AOI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2</td>
<td>9 (36%)</td>
<td>16 (64%)</td>
<td>25</td>
</tr>
<tr>
<td>V3</td>
<td>5 (20%)</td>
<td>20 (80%)</td>
<td>25</td>
</tr>
<tr>
<td>V4</td>
<td>6 (24%)</td>
<td>19 (76%)</td>
<td>25</td>
</tr>
</tbody>
</table>

Note:

- V1 was eliminated from this analysis because it did not have the graphical component.
- V5 was also eliminated from this analysis because the screen first presented to the participants in this variation did not contain any text (Figure 29).
- Sequence represents the order of gaze hit in the AOIs. It is based on the entry time in that AOI therefore, lowest entry time will be the first in sequence.

Observations

Sequence data from SMI-BeGaze reveals the order in which the participant had the first entered the AOI as he entered the stimulus screen. We were interested to see the sequence in which participants viewed text and graphic AOIs as a measure of their preference between text and graphical information where both were provided on the screen.

Figure 31: First View (Sequence) Analysis for V2, V3, and V4
Analysis

The sequence data from SMI-BeGaze for the variations V2, V3, and V4 shows that most participants went to look at the graphic AOI first as they entered the treatment screen. In variation V2, a relatively higher number of people looked at the text AOI first. Variation V2 had textual information displayed on the left with a simple graphic with no annotations on it on the right of the screen. This suggests a possibility that more people tend to look at the graphic first when graphics are accompanied with some annotations on them.

Measure 2: time learners spend on each of these areas

To investigate how learners processed the information from textual and graphical AOIs, we were interested in looking at the amount of time participants spent on each of these AOIs when learning a concept in variations V1 to V4. Therefore, we looked at the total dwell time for these AOIs in variations V1, V2, V3, and V4.

Total Dwell Time is defined as the time eye enters an AOI till it leaves it.

Data: Total dwell time data (Table 12) indicating how much time participants spent in viewing the textual and graphical AOIs was extracted from BeGaze analysis tool. This data only included the treatment slide for the concept. It did not consider the time spent on the examples slides or question slides.

<table>
<thead>
<tr>
<th>Variation</th>
<th>V1 (ms)</th>
<th>V2 (ms)</th>
<th>V3 (ms)</th>
<th>V4 (ms)</th>
<th>Avg Dwell Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>514335</td>
<td>435475</td>
<td>516366</td>
<td>444064</td>
<td>19102.4</td>
</tr>
<tr>
<td>Graphics</td>
<td>137301</td>
<td>198623</td>
<td>366062</td>
<td>935981333333333</td>
<td>935981333333333</td>
</tr>
</tbody>
</table>

Observations

Total dwell time data (Figure 32) indicates that participants spent more time on text than on graphics across all variations.
Figure 32: Total Dwell Time for Text and Graphic AOIs in V1, V2, V3, V4

To check if there was any statistically significant difference in the Total dwell times between text and graphic AOIs, data was subjected to the Moods Median test for variations V2, V3, and V4. Note: The data was checked for normalcy and since it was non-normal with outliers, Moods Median test was chosen for the analysis (See Appendix C: Attachment 3).

**Text AOI**
Moods Median Test for text AOIs for V1, V2, V3, and V4 did not show any significant difference (Appendix C: Attachment 4).

**Graphic AOI**
Moods Median test results for graphic AOIs in V2, V3, and V4 gave P-value of 0.000 indicating a significant difference (Figure 33) in the total dwell time for graphics between V2, V3, and V4.
Note: V1 was eliminated for dwell time analysis for graphics analysis since it did not have the graphic component.

**Analysis**

The total dwell time for text AOI remained consistently greater than the total dwell time for graphics AOI across variations V2, V3, and V4. In case of graphic AOI, the total dwell time data for the graphic AOI in variations V2, V3, and V4 was found to be significantly different from each other. The results clearly indicate higher median dwell time in graphic AOI for V4. Higher total dwell time is considered an indicative measure of more cognitively demanding activity. As we see in case of V4 there is a sharp increase in the dwell time on graphic AOI, which might be a result of more cognitive demand in the graphic AOI in V4. As explained earlier, V4 presented graphical information in most complete form with attention focus and labels. This presents a possible case of information overload in V4.

**Measure 3: how many times do learners need to revisit these areas to assimilate information**

We were interested in analyzing participants visit counts in text and graphic AOIs to understand how often they needed to go back and forth between these AOIs to learn concepts. Higher revisits on an AOI being an indicator of higher workload on an area, revisit data could indicate how the text and graphic components contributed to the cognitive workload and learning.

Revisit: Revisit is defined as the count of visits (or glances) on an AOI.
Data: The data for this analysis was extracted and then collated for each variation by using BeGaze analysis tools.

Observations

The bar chart (Figure 34) indicates that number of revisits in graphics AOI in V2, V3, and V4 increases as the amount of information on the graphics (attention focus and labels) increase from V1 to V4.

![Revisits Count for V1 to V4](image)

*Figure 34: Revisits Count V1 to V4*

To further investigate statistical difference in revisits count in text and graphic AOIs, the data was subjected to Moods Median test (since data was non-normal). However, Moods Median tests for text and graphics AOIs did not find any significant difference in revisit counts between V1 to V4 (Appendix C: Attachment 48).

Analysis

The revisits to the text AOI do not show a lot of variation, however graphics AOI show increasing revisit counts from V2 to V4. In case of V4, graphic AOIs get slightly higher number of revisits as the text AOI. This again points to the case where the amount of information in V4 is probably not helping to ease out the cognitive workload.
4.5 Research Question 4

How does learner-controlled progressive presentation of information change learner’s interaction with the content?

From our previous analysis, we found that variation that had most complete information (V4) did not result in better performance. Variation V5 presented an interesting case with same amount of information as in V4 but with learner-controlled progressive presentation of information. Previous analysis on the performance indicated a possibility that participants did better in V5 than in V4, we were interested to understand the change in learner behavior between these two variations.

**Measure:** The change in learner behavior between V4 and V5 was evaluated using the following measures:

• Measure 1: how much time did participants spent on content for variation V4 and V5 (time on task)

• Measure 2: how frequently and for how long did participants had to fixate on the content for variations V4 and V5 (fixation duration and frequency)

**Measure 1: how much time did participants spent on content for variation V4 and V5**

**Data:** Since the amount of information in V4 and V5 was same, the time that participants spent on treatment screen (time on task) was an important indicator of learner behavior with these two variations.

The time data that each participant spent on V4 and V5 was extracted from the time coded video recorded by SMI – Experiment Center. We considered only the time a participant entered the treatment screen to the time she clicked Next button to go to the next screen was recorded for the purpose of this analysis. It did not include the time spent on examples screens and test questions screens.

**Observations**

Figure 35 shows the average time participants took on screens with variation V4 and V5.
Anderson Darling test on time data indicated that the data for V4 and V5 was normal (Figure 36 and 37). Therefore, to check for significant difference in the time for V4 and V5, the data was subjected to ANOVA (Figure 38).
Analysis

The results of ANOVA did not indicate any conclusive evidence of statistical difference in the time spent on the task in V4 and V5. Therefore, we can say that the time that participants spent on information for V4 and V5 was approximately the same, and giving control of pace to the learner did not alter the overall time they needed to process information.
Measure 2: how frequently and for how long did participants have to fixate on the content for variations V4 and V5

From our earlier analysis, we found that participants scored better in V5 than in V4. Since the information in variations V4 and V5 was equal, and we also know that the overall time on task for V4 and V5 was the same, our next point of interest was to understand if the control of pace (in V5) had any change in how learner assimilated the information.

Data: To understand the cognitive activity with these two variations, we analyzed fixation counts and fixations durations of the participants on variations V4 and V5. For the purpose of this analysis, we considered fixations that were between 100 ms and 600 ms. Fixations below 100 ms and greater than 600 ms were eliminated as noise.

Observations

We plotted number if fixations and average fixations durations between variations V4 and V5 (Figure 39 and Figure 40).

![Number of Fixations between V4 and V5](image)

*Figure 39: Number of Fixations between V4 and V5*
The bar chart for Fixation Counts between V4 and V5 (Figure 39) shows that participants had more number of fixations in V5 than in V4. On the other hand, the average duration of fixation (Figure 40) was lesser in V5 than in V4. Therefore, it looks like participants had more number of shorter fixations in V5 when compared to V4.

We further analyzed this data to check if this difference in fixation durations is statistically significant. We ran one-way ANOVA with Tukey test on the fixation durations for V4 and V5 (Figure 41).
One-way ANOVA: Average Fixation Durations in V4 and V5

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>43531</td>
<td>43531</td>
<td>4.12</td>
<td>0.042</td>
</tr>
<tr>
<td>Error</td>
<td>5880</td>
<td>62129404</td>
<td>10566</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5881</td>
<td>62172935</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S = 102.8   R-Sq = 0.07%   R-Sq(adj) = 0.05%

Individual 95% CIs For Mean Based on Pooled StDev

<table>
<thead>
<tr>
<th>Level</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V4</td>
<td>2894</td>
<td>223.2</td>
<td>100.9</td>
<td>(------*------)</td>
</tr>
<tr>
<td>V5</td>
<td>2988</td>
<td>217.8</td>
<td>104.6</td>
<td>(------*------)</td>
</tr>
</tbody>
</table>

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method

<table>
<thead>
<tr>
<th>C1</th>
<th>N</th>
<th>Mean</th>
<th>Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>V4</td>
<td>2894</td>
<td>223.2</td>
<td>A</td>
</tr>
<tr>
<td>V5</td>
<td>2988</td>
<td>217.8</td>
<td>B</td>
</tr>
</tbody>
</table>

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of C1

Individual confidence level = 95.00%

C1 = V4 subtracted from:

<table>
<thead>
<tr>
<th>C1 Lower</th>
<th>Center</th>
<th>Upper</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V5</td>
<td>-10.7</td>
<td>-5.4</td>
<td>-0.2</td>
</tr>
</tbody>
</table>

Figure 41: One-Way ANOVA Result for Fixation Durations between V4 and V5

Analysis

The results of this analysis show a strong difference between the fixation durations for V4 and V5. V5 received more number of fixations of shorter durations versus lesser number of fixations of longer durations in V4. Research show that longer fixations reflect more cognitive processing (Sweller et al., 2011, pg 81). In this case reduced durations of fixations in V5 suggest possible decrease in the cognitive load when presented with more information in smaller units and with learner controlled pace.
4.6 Qualitative Analysis

All 25 participants were subjected to the post-session questionnaire (Appendix B: Attachment 7) to gather their preferences and opinions on variations and experiences.

Preference for Variations (Figure 39)

- 13 of 25 (52%) participants said that they preferred V5
- 4 of 25 (16%) participants preferred V4
- 7 of 25 (28%) participants preferred V3
- 1 of 25 (4%) participants preferred V2
- None participant preferred V1

Preference for Text or Graphic Areas

- 56% of participants reported they prefer to read text and look at graphics intermittently
- 28% of participants said they read the graphics first and then read the text
- 16% said they read the text first and then look at the graphics

Opinion on Effectiveness of eLearning
• 18 of 125 (82%) of participants reported that they do not find eLearning to be as effective as the classroom based learning
• 6 of 25 (24%) participants reported that they find eLearning to be as effective as classroom learning
• 1 out of 25 (4%) participant did not respond to this question

Note: Please see Appendix B: Attachment 9 for the actual responses of the participants.
Chapter 5: Discussion

The research questions for this study were mainly concerned with the effectiveness of combination of text, graphic, and annotations and learner behavior with them. We expected to find clear indications of the effectiveness in variations of text, graphics, and annotations in concept learning. However, results were not statistically conclusive to support that any of the tested combinations resulted in better learning and performance. Although not proven statistically, we found evidence of the case where too less (V1) and too much information (V4) did not work well for participants’ performance. The most interesting case was found between V2 and V4 where, V2 presented textual information with no annotations on graphic and V4 with textual information with heavily annotated graphic. Looking at the analysis for these two variations comprehensively (Figure 43), we see that participants scored comparatively well in V2 (mean score 3.82) than in V4 (mean score 2.84). We also recorded lower dwell time and revisit counts in V2, which is indicative that participants experienced lower cognitive workload in V2 in comparison to V4. Yet, self-reported preference shows only 4% (1 of 25) participants preferred this variation. Clark (1982) in his study found evidences of negative correlation between the learner achievement and what they feel they prefer as an instructional method/material. In this study we see a similar trend where learners did not enjoy the presentation format in which they performed the best.

Figure 43: Comparative Analysis between V2 and V4
On the effect of learner-controlled progressive presentation on learning a concept, statistical analysis for this variable was found very close to significance (p-value = 0.083). The mind-eye theory suggests, the eye remain fixated on an area while the information is being actively processed (Just and Carpenter, 1980). Therefore, fixation duration corresponds to the amount of cognitive processing needed for a piece of information. In this case, we found the fixation durations in V4 were significantly higher than the fixation duration in V5, which presented the same information in smaller units and progressive steps. The results indicate that when content is too heavy with textual and graphical information, providing some amount of learner control on the information display might help learner to assimilate information better. Additionally, we also found that providing more information on graphics may not necessarily be helpful in learning concepts. The results indicated that graphics with more information or annotations (attention focus and labels) was possibly causing increased workload for learners and required more revisits and time to create the mental model of the concept. This is an interesting finding and needs to be explored further with a more robust experimental design.

We also saw some interesting learner behavior with the text and graphic information. The study used eye-tracking measures of revisit and dwell time on text and graphic areas of content. The results of these analyses were statistically non-conclusive. However, we detected a possible pattern in the attention gained by graphics. We found that while presence of graphics may not necessarily reduce attention on text or even alter the order of processing information between text and graphic, most learners are inclined to look at graphics before the text when presented with a screen that has both. This finding inclines with the Mackworth & Morandi’s theory (1967) that human eye is most likely to be drawn to the perceived informative areas within first few second of viewing. This finding needs to be further studied with more detailed experiments to investigate if it also alters or impacts the order of processing information in the learning environments.

The qualitative analysis pointed to some other related factors that influence the effectiveness of eLearning. 82% of the participants who reported that they did not find eLearning to be as effective as the classroom learning based their opinion on two major factors: interactions and motivation. Participants reported that they found eLearning courses to be just content on the screen on which they have no control, lacks agility of face-to-face interactions, do not support active discussions, and provides no engagement with the content. There were also contrasting
opinions about the flexibility offered by eLearning environments. Some participants felt that too much flexibility in terms of pace and performance in eLearning environment results in lack of motivation. Classroom environment creates a pressure to stay attentive in class, peer competition, and need to actively engage with the content in classroom and therefore helps them to stay focused and motivated. On the other hand, participants who reported that they find eLearning to be as effective as classroom learning based their opinions on the flexibility of time and content that is offered by eLearning. They also reported video and audio components being helpful in the learning process.

Looking at the findings of this study comprehensively, the observations indicate a clear need for more research and efforts to understand usability aspects and learner expectations with the instructional material in technology-supported learning environments. We also need to look at the design solutions to minimize cognitive workload associated with higher order learning.

Following section lists some learning from this study that should be considered and further investigated to make better learner experiences and more usable learning systems.

5.1 Implications on eLearning and Content Usability

Learner-controlled Progressive Presentation of Content

When we talk about user interfaces and interaction design, progressive disclosure is an important facet of design. It helps break the content into smaller and more comprehensible blocks of information. By using this principle in designing the learning environments with technology we can achieve:

- directing learner attention on the individual and smaller units of information
- making learner interact actively with the content
- reducing cluttered screens and cognitive workload
- providing control on pace of learning to the learner

In concept learning, displaying each attribute separately with corresponding elaboration on the graphic (attention focus) and providing control of pace in the learner’s hands, can help learner create better mental model of the variables/attributes of concept and foster engagement with the content in more interactive way. Additionally, in context of mobile learning or designing
learning environments for smaller screens where trade-offs are required between content and screen design, progressive presentation can be an alternative solution.

**Amount of Information for Optimal Learning**

One participant commented “Annotations on graphics plus text on the screen feels too busy to me. I ignored the annotations because it felt like information overload.”

Illustrated annotations are considered as a most effective way of helping people learn in static and animated mediums. In their study Mayer et al. (2005) suggests that static illustrations and text treatments allow learners to control the pace and order of information processing. This format of information presentation helps deeper engagement with the content and allows learner to go back and forth between text and corresponding illustration, creating a mental map between words and illustration. However, this study raised a question: what amount of information is optimum for learning and when does it become ‘too much information’? Results of this study indicate that what we as designers of information consider as complete information, might actually pose a case of cluttered screen and information overload for the participants. This is an interesting area that can be explored further to investigate if what comes as an interesting and complete visual stimulus also aids better understanding and vice versa.

**Engagement with the Content and People**

One of the prominent reflections that came up in this experiment is the expectation of learner with content in eLearning environment. Participants considered eLearning to be primarily a visual medium with passive information exchange with instructors and peers. It is clear from the responses that learners give high value to the audio, visual, and spatial interactions with people, material, and environment in learning process. There is also an implicit expectation of replication of the classroom learning environment and greater engagement with content and people.

Several participants commented supported this

“Classroom setting often includes real world examples and demonstrations.”

“I focus better and retain more when listening to lecture and taking my own notes.”

“Graphics and animated illustrations are good in eLearning, more visual learning is possible.”
Looking at it from a content usability view, motivation to use the content is an important aspect that needs to be addressed in eLearning environment. It is important that the learner is not only able to access the right content when needed but is also able to use it with ease and flexibility of the classroom environment. Appropriate use of annotation tools, notes area, instructor and peer collaboration areas, and audio can help developing better learner engagement with content and environment.

**Pedagogical Usability**

Electronic medium offers an extended canvas to eLearning design with multi-modal channels to present content. However, this flexibility also presents a challenge in achieving balance in delivering right amount of content using auditory, visual, and tactile mediums. Results of the study are indicative of the need to decide right amount of information for optimal learning and learner satisfaction. It certainly points to the case of evaluating effective value in having same information delivered though textual and graphical forms; learners found it overwhelming and unnecessary. Finally, the objective of all learning environments, tools, and methodologies is to transfer knowledge and is a direct measure of achieving the learning goals. As defined by Nokelainen (2006), pedagogical usability refers to achieving the goals set for a learning environment including the technical equipment, learning material, learner, and instructor. The learning material, tools, and delivery methodology all must come in-sync to support the learning goals set by the learner. The flexibility offered by technology must be used with right context and content and for the intended learning outcomes. While passive content screens do not add much value to the learning environment, unnecessary information, interactions, or animation might create additional workload for learner.

**5.2 Possible Recommendations for Design**

Based on our learning from this study, we suggest the following considerations that might help in designing better technology-supported learning environments:

- Results of this study points to the theory of learner control as a way to improve learner performance and satisfaction with the learning material. It is evident that providing some sort of controlled display of information unclutters the screen and helps learner not to feel
overwhelmed by the amount of information although he is still going through the same amount.

• Gradual and step-by-step presentation of attributes helps learner to create better attribute associations and mental models of the concepts. As Cooper (1998) suggests presenting smaller chunks of elements helps facilitate cognitive processes associated with learning and remembering.

• When presented with text, annotated graphics demand more cognitive effort and thus content needs a balance between textual and graphical information to minimize the load and still attain efficiency in processing information.

• Content and interactions keep learners motivated and engaged. These two elements must be designed with care. Features like annotatable areas, interactions with peers and instructors can help learner engage better with content and environment. While navigational elements need to be clearly available, they must not compete with the interactive elements of the content.

5.3 Future Considerations

The questions studied in this study brought out several areas that can be evaluated further for their applicability in designing more usable learning environments. The following section discusses some of these findings that can be explored further to understand learner behavior with the content in technology supported learning environment.

Learning Styles

“Some people are better at processing words and some people are better at processing pictures” - -Mayer and Massa (2003, p.833).

While the result from this study does not amount to the fact that participants also processed the graphic information first, it certainly indicates that in most cases graphics catch learners’ attention first. Additionally, on probing on the order they process information, most participants (56%) indicated that they follow a one-to-one approach between textual information and corresponding graphical information. 28% of the participants also indicated their preference to read graphics first. It would be interesting to investigate eye movement patterns in information processing to understand the learning styles.
Conditioning Effect of Discipline

It is also interesting to note that 3 of the 7 participants that indicated their preference to process graphical information first were from engineering disciplines. Some disciplines are inherently more text oriented and others require considerable graphical information. Does a learner’s background in a certain discipline condition the way he process information? It could be an interesting area to investigate if the preference and behavior towards text and graphic is linked with the discipline. Future studies can be designed to bring out the effect of discipline background on learning.

Audio as a Variable

Audio was not included in the study. It would be interesting to see the effects of audio on learning with combinations of text, graphics and annotations. Future studies can also be designed with variations such as only graphics and audio to replace text.

5.4 Limitations of the Study

The study suffered from some design flaws that contributed to the inconclusive results.

1. Variations were too many and the differences were too subtle. The study would have provided better data if there were fewer variations with more apparent differences in the presentation of content.

2. The concepts that were chosen for the study were generic and although care was taken while recruiting the participants to negate the possibility of pre-knowledge, the concepts were probably too easy and could not bring out the real difference in learning. As an improvement for the future studies, the researcher recommends using stronger concepts.

3. Each concept was followed by examples before subjects took the questions. The examples helped participants to retain already easy concepts. As an improvement, the examples should be removed from the stimulus.

4. Time limitation allowed only four questions per concept. Having more questions and more participants would help getting a more robust and normal data for performance analysis.

5. A more careful screen design with clearly separated text, graphic, and navigational areas would be helpful to avoid noise data in areas of interest.
6. The treatment of the content was somewhat predictable in the study. The placement and treatment of text, graphics, and annotations was kept the same for all concepts and, although the order of variations and concepts was changed for each participant, participants were probably conditioned after the second concept to expect similar treatment for other concepts.

5.4.1 Noise Data

1. A lot of noise data (long fixations) was recorded by the eye tracker for the participants. This noise was caused by interface elements and other than the content or the Areas of Interest (AOIs). This included the Next button located at the bottom right corner of the screen. Especially, for variations V3, V4, and V5 this button was too close to the graphic AOI and probably caught a lot of attention. The fixations on the button were eliminated from the data.

2. The AOIs on the screen were very closely placed and considering calibration error, a lot of noise data was generated due to the overlap near the boundaries of AOIs.

3. Some noise data also resulted from participants asking questions while not taking their eyes off from the screen. The questions were like “how long is the session”, “how many sections are there?”, “can I go back to the previous page?”, and so on. This data was eliminated from the study by considering fixations only between 100 ms – 600 ms.

4. Some participants were extra attentive to the content on the screen since they were aware that they were being eye tracked and that they will be answering the questions. This was not a normal behavior in natural learning environment and resulted in long fixations.
Chapter 6: Conclusion

Although the results of this study did not show strong conclusive trends or patterns in learner behavior, it did bring out some rather interesting aspects in content usability, perceptual processing, and learner behavior that can be explored and researched further with more directed and robust studies. There is a clear need for designing better eLearning environments that are conducive to learning and provide better learner experience with content and interactions. We cannot change the intrinsic load that is inherent to the subject or content but with better understanding of learner behavior with electronically delivered content, we can reduce the extraneous load that is associated with the design aspects of content, modality, and delivery. More research is required in learner behavior with electronically delivered content and its usability for technology to be able to support effective learning environments.
Glossary of Eye Tracking Terms Used

The following technical definitions are used in this document:

**Fixations**: Fixations are the eye movements that occur when eyes stabilize over an area of visual interest. Fixations are considered to occur when some active visual processing is taking place. Longer fixations are considered to be associated with heavier cognitive activities.

**Saccades**: Saccades are the rapid eye movements used in repositioning the fovea to a new location on the visual space. Saccades occur between the fixations and are considered not to contribute to the visual processing.

**Area of Interest**: The area defined on the screen where we want to analyze the eye movements.

**Fixation Durations**: The duration for which eye fixate on a point of visual interest. It is generally measured in milliseconds. The meaningful fixation durations are. For a meaningful visual processing to occur, eye must fixate on the point of interest for a minimum period of time. This period can be from 100 ms to 600 ms depending on different types of visual activities.

**Fixation Count**: The count of meaningful fixation occurring on a visual space.

**Total Dwell Time**: Total dwell time is time at which the eye enters the AOI until it leaves it.

**Calibration**: Calibration is the process where the eye tracking system establishes the relationship between the position of the eye in the camera view and a gaze point in space, the so-called point of regard (POR). The calibration also establishes the plane in space where eye movements are rendered.
References


(http://www.sciencedirect.com/science/article/pii/S0360131506001874)


Von, R. H. 1933. Uber dieWirkung von BereichsbildungemimSpurenfeld (The effects of field formation in the trace field). PsychologieForschung 18, 299–334

http://content.epnet.com.ezproxy.rit.edu/pdf23_24/pdf/2010/EPY/01Jan10/49152722.pdf?T =P&P=AN&K=49152722&EscoContent=dGJyMNHX8kSep7A4y9f3OLCmr0qep7FSsg 24SbCWxWXS&ContentCustomer=dGJyMPGutlC1r7dNuePfgeyx%2BEu3q64A&D=afh

Royalty free images were used in creating the graphics used in this study. Images were downloaded from Google Images and Getty Images.
Appendix A: Additional Investigations

To check for other possible relationships between the data values, we conducted some additional tests on the data. Although these tests were not directly related with the research questions but provided us an opportunity to detect any other possible relationships. We explored some individual difference variables, such as educational qualification (graduates and undergraduates), prior experience with eLearning, pace adopted to complete the sessions, and so on to evaluate if they have an influence on the results. While we found some correlations, we did not find any significant impact of these variables in using these in exploratory analysis.

Following are some of the additional questions we tried to explore with the collected data.

1. Did participant who had prior experience with eLearning scored better?
   Experience with eLearning was not a required factor for participation in the study; however, we were interested to know if participants who had prior experience with eLearning performed better than those who did not have any experience with eLearning. Pearson correlation coefficient (0.26) did not show any strong relationship between participants’ scores and their prior eLearning experience.

2. Did participants who took more time to complete the study scored better or worse than others?
   The study was designed to be self paced with participants having complete control on timing themselves. Start to finish time data shows that participants took minimum 7.40 minutes to maximum 15.59 minutes to complete the session. We were therefore interested in looking at the time influence on the scores. Pearson correlation coefficient (0.07) indicated that scores were not influenced by the time taken by participants to complete the session.

3. Is learner behavior with text and graphics related to the subject’s nature of discipline?
   During the course of sessions, at least three of the 25 participants pointed that when complete information is provided on the graphic, they tend to ignore the text. Two of these participants were from Engineering disciplines and one was from Computer Science. This observation sparked the question if learner’s discipline has some influence on his behavior with the
content. Since the participants in this study came from varied discipline background, we grouped the disciplines into STEM and non-STEM disciplines to check if there is a correlation between participant’s discipline and their scores. We failed to find any strong correlation between the performance of participants and their disciplines.

4. Did graduate participants do better than the under-graduate participants or vice-versa?

We also explored the possibility of level of educational qualifications on the performance of participants. We categorized the participants in two groups; graduate and under-graduate. Correlation analysis on the performance scores of graduate and undergraduate participants showed moderate negative correlation (-0.309) of scores with their educational qualifications; the performance of participants decreased for graduate participants. However, further analysis with two-way ANOVA, we did not find any significant results.
Appendix B: Test Material

Attachment 1: Recruitment Flyer

Take a Break!
Participate in an Eye Tracking Research Study

Inviting participation in my masters research study on Understanding the Presentation Styles and Concept Learning

The session will take about 30 minutes of your time.

To participate: You must be between 18 – 35 years, be able to read, write, and speak English, and be able to use a computer.

Take a small break and participate in an interesting study!
Your cup of steaming hot coffee at Java’s and cookies is on me. 😊

Call at 315 921 6340 or write at nxs3136@rit.edu to schedule a session.
Principal Investigator: Nivedita Singh
Attachment 2: Screener

An Eye Tracking Approach to Understand Concept Learning

Age:
- 18 - 21
- 22 - 25
- 26 – 30
- 31 and above

Gender:
- Male
- Female

Education:
- Undergraduate
- Graduate
- Others

Proficiency with Computers
- No experience using computers
- Moderate (use computers for homework, games, shopping, etc)
- Very Proficient (software developer/engineer, web developer, coder)

Proficiency with English
- Basic (can speak just enough to converse)
- Moderate (can read, write, and speak with reasonable fluency)
- Very Proficient (can read, write, and speak with fluency)

Have you ever worked as a:
- Bank Teller
- In a courier company or a post office
- Wine Brewery
Attachment 3: Test Script

An Eye Tracking Approach to Understand Concept Learning

Thank you very much for your interest to take part in my research study.

This is the consent form from RIT, please go ahead and read it, and if you agree, please sign it.

I'm here to learn how learners’ interact with the content in electronically enhanced learning environment. This study aims to understand and improve the learners’ experience with the conceptual content in electronically delivered learning material. During the test session, I will ask you to go through a set of selected conceptual content and answer questions based on the presented content. As you go through the content and answer the questions, you will be eye tracked using SMI Remote Eye Tracking system, which is a non-invasive technology for eye tracking. You will not be required to wear any glasses or equipment during the session. You will go interact with the content presented on the screen as you would with any eLearning module. Your responses to the questions presented will be recorded for analysis in the study.

Please remember that I'm not testing you, the experiment is designed to test the effectiveness of the presentation of content in the eLearning environment. Your taking part in this experiment helps me understand how information presentation on the screen might help learning the content better and faster.

Please be as comfortable as you would take any other eLearning module. The questions presented with the content will be multiple choice types and will not be timed. However, you will not be able to go back to the content once you are in the question screen.

Your participation in this experiment is completely voluntary and you may discontinue your participation at anytime during the session. The complete session will take about 30 minutes of your time however, due to the limitations of the eye tracking instrument, you will not be able to take a break during the session.

If you have any questions at this point, please let me know.

Thanks.
Attachment 4: Consent Form

An Eye Tracking Approach to Understand Concept Learning

Welcome! I invite you to participate in a research study that will look into the different content presentation strategies on the electronic medium. Please let me know if you have any questions at any time during or after the session.

INFORMATION

During the session, you will be presented with the content in a certain sequence. You will go through the content as you would in any eLearning module and will be asked to answer a few questions based on the covered content. All through the session you will also be eye tracked with the equipment used in this study. You will not require wearing any glasses, lenses, or equipment for eye tracking. The equipment used is a non-invasive technology for eye tracking. The eye tracking equipment will record your eye movements on the screen as you go through the content and answer the questions. This recording data and your responses to the questions will be analyzed in this study. The session should last approximately 30 minutes.

PARTICIPATION

We reserve the right to stop the study early if we believe it to be necessary. Similarly, you may choose to stop participating at any time before or during the session without any consequence.

RISKS AND BENEFITS

This study involves no perceived risks, physical or non-physical, nor will it provide any benefit to you directly. That been said, the information gathered here will be used to better design future eLearning material and guide researchers in the field.

CONFIDENTIALITY

Your name will not be used in the publication of this data. All information will be identified solely by a participant number. Every effort will be made to maintain the confidentiality of all information obtained.

CONTACT

If you have any questions or concerns regarding the study or unexpected results you may contact Nivedita Singh at (315) 921-6340 or email me at nxs3136@rit.edu.

CONSENT

I have read and understand the above information and wish to participate in this study.

Signature of Participant: ___________________________ Date: ___________________________

Signature of Investigator: ___________________________ Date: ___________________________
Attachment 5: Background Questionnaire

An Eye Tracking Approach to Understand Concept Learning

Age:
- 18 - 21
- 22 - 25
- 26 - 30

Gender:
- Male
- Female

Education:
- Undergraduate
- Graduate

Program/Major:

Experience with eLearning Modules:
- No experience/never taken an eLearning course
- 1 - 3 courses
- 4 or more courses
Attachment 6: Post Session Questionnaire

An Eye Tracking Approach to Understand Concept Learning

Ques 1. Of the five different presentation formats that you saw in this session, which one do you prefer?
   - text with no graphics
   - text with no annotation on graphics
   - text with partial annotation of graphics
   - complete text with complete and static annotations on the graphics
   - text with complete and animated display of annotation on the graphics

Ques 2. When presented with content with text and graphics, do you prefer to:
   - Read the text first and then look at the accompanied graphics
   - Look at the graphics first and then read the text
   - Read the text and look at the graphics intermittently
   - Don’t look at the graphics at all
   - Don’t read the text at all
   - Other (please explain)

Ques 3. Have you ever taken an eLearning course/module?
   - Yes
   - No

Ques 4. Do you find eLearning courses to be as effective as the face-to-face classroom courses?
   - Yes
   - No

Why?

Ques 5. Would you like to share any other experiences/observations during this session.
Attachment 8: Post-Session Debrief

I appreciate your participation and time for this experiment. The information and the data I collected from today’s session will only be used for the research analysis and will be kept completely confidential. This data will help me understand how learners interact with the content in different formats, and eventually recommend effective content presentation strategies for the conceptual learning.

If you have any further questions or concerns, you are welcome to contact me at any time on my email, nxs3136@rit.edu.

Thanks again for taking time to participate in this study.

Here is your coffee coupon for Java’s. Enjoy your cup of coffee.
Attachment 9: Responses on Effectiveness of eLearning

An Eye Tracking Approach to Understanding Concept Learning

The following reasons were given by 23 participants to justify their response to the question: Do you find e-Learning to be as effective as the face to face classroom learning? Why?

Two participants chose not to elaborate on their response:

- Need to be more focused
- Can’t talk and see the Professor directly
- Physical presence of instructor
- Classroom interactions missing, online is good if it doesn’t require discussions/interactions
- Instructors presence is good for interactions and discussions
- On computer based learning, you need more attention. Can hear voices in classroom, Audio makes a difference in learning
- More face to face interactions in classroom. Also, eLearning takes less time to go through the content and so I have to pay more attention to the content. Would want to have the control to revisit content. eLearning has some good and some bad aspects
- Lacks motivation and it is not completely interactive
- Some amount of face to face interaction helps
- Lack of interaction
- They tend to be mostly text with no user controlled display
- Classroom setting often includes real world examples and demonstrations
- I focus better and retain more information when listening to teacher and taking notes
- I learn best when I communicate with an instructor and engage with the material
- They tend to be just text with no user controlled display
- I don’t feel the pressure to be an active participant. I am not all IN. I could be distracted by my environment
- No one to attract or control my attention in elearning courses
- Headache, sleepiness (because of screen brightness), cannot clear my doubts
- No classroom/student distractions. Time convenience. Videos are effective.
- It let me control the flow of information
- Because I can do it in my own pace
- Because I can arrange my time and schedule
Appendix C: Additional Information

Attachment 1: Tests to Check Complexity between Concepts

Table 13: Scores Data for Participants (Concepts)

<table>
<thead>
<tr>
<th>Participant#</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1S1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>P2S2</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>P3S3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>P4S4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>P5S5</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>P6S1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>P7S2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>P8S3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>P9S4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>P10S5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>P11S1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>P12S2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>P13S3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>P14S4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>P15S5</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>P16S1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>P17S2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>P18S3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>P19S4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>P20S5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>P21S1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>P22S2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>P23S3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>P24S4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>P25S5</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
</tbody>
</table>
Histograms of the Score Data for Concepts (C1 to C5)

**Figure 42: Histograms for Scores C1 to C5**
Chi-Square Test Results between Concepts Scores

Chi-Square Test between scores C1, C2, C3, C4, C5

Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
<td>81</td>
<td>71</td>
<td>78</td>
<td>75</td>
<td>388</td>
</tr>
<tr>
<td></td>
<td>77.60</td>
<td>77.60</td>
<td>77.60</td>
<td>77.60</td>
<td>77.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.376</td>
<td>0.149</td>
<td>0.561</td>
<td>0.002</td>
<td>0.087</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>19</td>
<td>29</td>
<td>22</td>
<td>25</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>22.40</td>
<td>22.40</td>
<td>22.40</td>
<td>22.40</td>
<td>22.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.302</td>
<td>0.516</td>
<td>1.945</td>
<td>0.007</td>
<td>0.302</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>500</td>
</tr>
</tbody>
</table>

Chi-Sq = 5.247, DF = 4, P-Value = 0.263

Figure 43: Anderson Darling Test for Scores (C1 to C5)

Figure 44: Chi-Square Test to Check Complexity between Concepts
Attachment 2: Normalcy Test on Score Data for Variations

Figure 45: Histograms for Scores V1 to V5
Figure 46: Probability Plot for Scores V1 to V5

Attachment 3: Normality Test for Dwell Time

Figure 47: Probability Plot for Dwell Time for Text AOI(V1 to V4)
Attachment 4: Moods Median Test for Text AOI (V1 to V4)

Mood Median Test: Dwell Time (Text) versus Variation for Variations V1 to V4

Mood median test for Dwell Time
Chi-Square = 2.04    DF = 3    P = 0.564

<table>
<thead>
<tr>
<th>Variation</th>
<th>N&lt;=</th>
<th>N&gt;</th>
<th>Median</th>
<th>Q3-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>13</td>
<td>12</td>
<td>16039</td>
<td>8257</td>
</tr>
<tr>
<td>V2</td>
<td>13</td>
<td>12</td>
<td>16039</td>
<td>8257</td>
</tr>
<tr>
<td>V3</td>
<td>15</td>
<td>10</td>
<td>13394</td>
<td>13229</td>
</tr>
<tr>
<td>V4</td>
<td>10</td>
<td>15</td>
<td>17729</td>
<td>15125</td>
</tr>
</tbody>
</table>

Overall median = 16039

Attachment 5: Test on Revisit CountsV1 to V5

Figure 48: Probability Plot for Revisit Count in Text AOI (V1 to V5)
Mood Median Test: Revisits versus Variation in Text AOI for V1 to V4

Mood median test for Revisits
Chi-Square = 0.97    DF = 3    P = 0.808

<table>
<thead>
<tr>
<th>Variation</th>
<th>N&lt;=</th>
<th>N&gt;</th>
<th>Median</th>
<th>Q3-Q1</th>
<th>Individual 95.0% CIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>14</td>
<td>11</td>
<td>7.00</td>
<td>6.50</td>
<td>(-----*---------------)</td>
</tr>
<tr>
<td>V2</td>
<td>15</td>
<td>10</td>
<td>7.00</td>
<td>5.50</td>
<td>(-----*-------)</td>
</tr>
<tr>
<td>V3</td>
<td>15</td>
<td>10</td>
<td>7.00</td>
<td>4.00</td>
<td>(-----*-----)</td>
</tr>
<tr>
<td>V4</td>
<td>12</td>
<td>13</td>
<td>8.00</td>
<td>7.50</td>
<td>(-----*-------)</td>
</tr>
</tbody>
</table>

Overall median = 7.00

Figure 49: Moods Median Test for Revisit Count in Text AOI (V1 to V4)

Attachment 6: Time on Task for each Concept with each Variation

Concept 1
- Median time on task for Concept 1 is highest for V5 (42784 ms).
- V1 has the least variation, indicating that participants took fairly consistent time in V1 for Concept 1.

Concept 2
- Median time on task for Concept 2 is highest for V5 (42784 ms).
- V2 has the lowest median and least variation, indicating that participants took fairly consistent time in V2 for Concept 2.
Inference:

- V2 (text and graphic with no annotations) shows least variation and lower median for Concepts 1, 2, and 3, which suggests that V2 is most efficient presentation for these concepts. Recalling the results of performance analysis, the scores for V2 were highest but not statistically significant.
Attachment 7: Dwell Analysis for Concepts in variations V1 to V5

**Concept 1**
- The dwell time in Text AOI is much higher than the dwell time in Graphics AOI for all the variations.

**Concept 2**
- Concept 2 shows the similar dwell time in Text and Graphics AOI for all the variations with dwell time on text being higher.

**Concept 3**
- Dwell time for concept 3 varies considerably between text and graphic AOIs.

**Concept 4**
- Concept 4 again has higher dwell times for Text AOI than Graphics AOI for all the variations.
Concept 5

- Concept 5 shows relatively higher dwell time for graphics AOI compared to other concepts.

The collective dwell time data (Figure below) for all the concepts for the five variations shows:

- Mean Dwell Time for Text AOI = 18682 ms and for graphics AOI = 10390 ms.
- Dwell time on text AOI is consistently higher in all the variations.
- Dwell time on graphic AOI is increasing in V2, V3, and V4 as the graphical information is increasing but goes down in V5 that has user control over display of information.
- V5 shows slightly lesser dwell time in both text and graphic AOIs compared to V4.

Figure 51: Dwell Time for Concepts 1 to 5
Attachment 8: Distribution of Total Time on Session

![Figure 52: Time to go Through the Session](image)

Participants were given the freedom to choose their own pace to go through the Flash application, and their time from start to finish was recorded.

- Least Time: 7.49 minutes
- Maximum Time: 15.59 minutes
- Average Time per session: 10.68 minutes

Attachment 9: Post Session Questionnaire Responses

All 25 participants were subjected to the following post-session questionnaire (Appendix B: Attachment 7) to gather their preferences and feedback.

**Question 1:** Of the five presentation formats that you saw in this session, which one do you prefer?

**Responses:**

- 13 of 25 (52%) participants said that they preferred V5
- 4 of 25 (16%) participants preferred V4
• 7 of 25 (28%) participants preferred V3
• 1 of 25 (4%) participants preferred V2
• None participant preferred V1

<table>
<thead>
<tr>
<th>Variation</th>
<th>V1 (Text with no graphics)</th>
<th>V2 (Text + no annotations on graphics)</th>
<th>V3 (Text + partial annotations on graphics)</th>
<th>V4 (Text + complete annotations on graphics)</th>
<th>V5 (Learner-controlled display of text and annotations on graphics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of People</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>

Most participants could not recall or identify the variations as they were asked this question and required the printed screen shots of content (Appendix A: Attachment 6) as reference.

**Question 2:** When presented with content with text and graphics, do you prefer to:
• read the text first and then look at accompanied graphics
• read the graphics first and then read the text
• read the text and look at the graphics intermittently
• do not look at the graphics at all
• do not read the text at all
• others

**Responses:**
• 56% of participants reported they prefer to read text and look at graphics intermittently
• 28% of participants said they read the graphics first and then read the text
• 16% said they read the text first and then look at the graphics
Table 15: Order of Content Preference

<table>
<thead>
<tr>
<th>Reading Preference</th>
<th>Read the text first and then look at accompanied graphics</th>
<th>Read the graphics first and then read the text</th>
<th>Read the text and look at the graphics intermittently</th>
<th>Do not look at the graphics at all</th>
<th>Do not read the text at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of People</td>
<td>4</td>
<td>7</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Question 3: Do you find e-Learning to be as effective as the face to face classroom learning? Why?

Responses:

- 18 of 125 (82%) of participants reported that they do not find eLearning to be as effective as the classroom based learning
- 6 of 25 (24%) participants reported that they find eLearning to be as effective as classroom learning
- 1 out of 25 (4%) participant did not respond to this question

Table 16: Opinion on Effectiveness of eLearning

<table>
<thead>
<tr>
<th>No of People</th>
<th>Yes, eLearning is as effective as classroom learning</th>
<th>No, eLearning is not as effective as classroom learning</th>
<th>Undecided</th>
<th>No Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>18</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Attachment 10: Calibration Error

Figure 53: Boxplot of Calibration Error