E-Textbook Evaluation Study

by

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Abstract

The effects that technological advances have on education and how these advances can be used to improve the learning process are important research questions that attract many researchers to study different aspects of these issues. One such aspect is the development of interactive e-textbooks. Interactive e-textbooks are defined as electronic books that go beyond the static nature of printed textbooks. In this study, an e-textbook was developed that uses JavaScript for its interactive elements, and employs a concept map for navigational purposes. This e-textbook prototype was tested for the purpose of answering the following research questions. Does an e-textbook improve a student's learning as measured by his/her performance in a test? Does an e-textbook improve a student's learning and performance better than a printed textbook? Do students like interacting with the interface of an e-textbook and does it increase a student's engagement with the course material? Results showed that undergraduate students' performance improved after using the e-textbook. Results also showed that both undergraduate students and graduate students had a positive reaction to the e-textbook.

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Chapter 1

Introduction

The effects that technological advances have on education and how these advances can be used to improve the learning process are research fields that attract a large number of researchers to study their many different aspects. One such aspect is the development of interactive e-textbooks. Interactive e-textbooks are defined as books that go beyond the static nature of printed textbooks.

The first chapter of this thesis explains what e-textbooks are and what characteristics they have over traditional printed textbooks. This chapter also reviews previous research on e-textbooks in terms of its contributions, achievements, the technologies used, and limitations. It also states our vision of an e-textbook, the motivation behind it and its requirements.

The rest of the thesis is structured as follows: the second chapter discusses the efforts that went toward developing an e-textbook prototype and how the requirements of our vision were met. It explains the functions provided to the user (student), the software architecture, and the user interface.

Methodology used to test the system is described in the third chapter. This chapter describes the procedure followed in three studies: the usability testing, pilot testing, and actual testing. The purpose of each testing, and the statistical tests used to analyze the collected data are also discussed.

Results of data analyses and their implications are discussed in the fourth chapter. We ask three research questions. Does an e-textbook improve student's performance? Does it improve student's performance better than a traditional printed text? Does it increase student's engagement with the material? T-tests aim to answer the first research question about the effect of e-textbooks on student performance and the second question that compares between the performances of students who used the e-textbook and students who used the printed textbook. The third research question is answered by analyzing students' answers to the user interface evaluation survey that measures students' reaction to the e-textbook.

Lastly, a conclusion is included along with suggestions for future work and how the developed prototype can be used as a basis for further research in the field of e-textbooks, which in turn can lead to advances in learning from e-textbooks.

Chapter 2

Literature Review

Advances in computer technology, especially interactive technologies, can potentially benefit the teaching and learning process tremendously. One area ripe for development is that of textbooks. Despite the proliferation of the web and mobile devices, textbooks remain mostly as printed hard copies. Even the so-called e-books are generally digitized versions of the printed textbooks with interactive elements such as video and animations embedded into them. In the present research, we explore the possibility of structuring knowledge in e-textbooks not as chapters and sections, but as small chunks of knowledge connected together in concept maps that students can interactively navigate through. In this chapter we discuss a few selected papers on the development and evaluation of interactive e-textbooks.

Interactive e-textbooks are defined as books that go beyond the static nature of printed textbooks. These books are often characterized by some or all of the following requirements:

- Interactive visualization
- Automatically assessed exercises that provide feedback to the learner
- Interactive learning activities
- Customization of content [3]

Many interactive e-textbooks have been developed on different science subjects, but especially in Computer Science as the nature of the field itself makes it intuitive to use this kind of tool in teaching.

One system that fulfils one of the previous requirements is Trakala2 for data structures and algorithms. Trakala2 provides interactive simulation exercises that allow students to manipulate data structures as the actual algorithm would. The system provides feedback and compares student's answer against a model answer. Several studies were conducted to see the effects of Trakala2 on students' learning processes and outcomes. One such study was done at Helisnki University of Technology with Computer Science students on a data structure and algorithms course. Two students were paired together and were assigned to either a viewing group or a changing group. Results showed performance differences between the two groups, indicating that it was important for students to engage and interact with the visualizations rather than just passively viewing them [4].

Another attempt at designing an e-textbook was the Computational Physics e-textbook created at Oregon State University. The developers chose a PDF format for the book to be accessible on any platform, and then added capabilities that made it more interactive, like video-based lectures that showed the professor explaining the topic alongside slides and links to codes and applets. The e-textbook also has Python simulations, executable equations and figures, a glossary for the different concepts and the ability to hear the definition of a word without leaving the page. An external assessment rated the e-textbook 4 out of 5 stars [5].

A research group from China and Germany built an e-textbook for a Theory of Computation course based on ActiveMath. ActiveMath is a web-based learning environment that adapts to the individual needs of each learner. The prototype of the e-textbook contained, among other things, interactive exercises that provided feedback to the students and measured their performance, and because of the adaptive nature of ActiveMath, the student model (the model that the system builds to assess students skills against the domain knowledge) updates dynamically to reflect the student's progress. The researchers are planning to improve this prototype by allowing students to post questions and instructors to grade and provide feedback. Also, they are planning to develop a concept map navigator that is color coded to reflect what concepts are well understood and what concepts need more work [2].

Sadhana, Stylianou and Hubscher (2003) discussed their motivation, design and efforts in building a Concept Mapped Project-Based Activity Scaffolding System (CoMPASS) in [8].

CoMPASS provides students with a concept map (a graphical representation of the domain knowledge) and a text, both of which change dynamically when the student navigates through the system. A study using CoMPASS with middle school students found that students who used the concept maps to navigate performed significantly better than students who used the system without the map [8].

Puntambekar and Stylianou (2005) reported another study that used CoMPASS. In this study, CoMPASS was used to analyze students' navigation patterns and group them into clusters. According to this analysis, students' navigation patterns were clustered into four groups, each requiring a different kind of support. Another study was later conducted, after using the first study as a basis to build different kinds of navigation support into CoMPASS. This second study had two groups of students, one group used the CoMPASS system with navigation support (prompts that provided hints to students about what concept or topics they need to view next), and the second one was not provided with the navigation support. Results from this study showed that students who had the navigation support performed better on a concept map test [9].

Shaffer, Karavirta, Korhonen and Naps (2011) described their efforts with OpenDSA, an interactive book for data structures and algorithms. This project builds upon previous experiences in the field to create an e-textbook that does not suffer from known problems and drawbacks. One such improvement is the use of HTML5 and JavaScript to author the content (static and dynamic). The reason behind this decision is that Flash and Java Applets that were used to build most of the previous e-textbooks require a plug-in to run and are not compatible (do not run) on tablet devices. Furthermore, to make content authoring an easier process, a specialized JavaScript library was developed; it is called JSAV (JavaScript Algorithm Visualization) library. The authors also acknowledged the tremendous effort that is required for such a project, and for that reason they sought an open source environment to host the e-textbook. This will attract more authors to take part in the project and create content for the book, and more developers to develop and build interactive elements. In addition, instructors will benefit by being able to arrange topics and units as they see fit for their individual courses and classes [10].

Miller and Ranum (2012) explained their vision for e-textbooks, how it was implemented, and the results of a trial. Their e-textbook included a number of features such as videos, code editing, execution, and visualization. It also used an open source authoring system to give instructors the ability to edit content. After using the e-textbook for teaching an Introduction to Computer Science course at Luther College for a semester, they reported results showing a positive reaction from students [6].

Alvarado et al. (2012) used the e-textbook developed by Miller and Ranum to explore how students use its features and how their usage affects their performance. Though these reseachers reported that students used the e-textbook much like a traditional textbook despite their high level of satisfaction with the e-textbook, they also reported that students, who used the e-textbook more outside of class hours, preformed higher on midterm exams [1].

With the current technological advances and the spread of tablet devices that do not support Java or Flash, an e-textbook that does not require these technologies is an ideal solution to the problems encountered in the previous research efforts. An e-textbook that is platform independent is better. In this study, an e-textbook prototype was developed according to this vision and above mentioned requirements (except for the inclusion of automatically assessed exercises). Interactive elements of the prototype were built with JavaScript making the e-textbook platform independent. Inspired by the CoMPASS e-textbook, a concept map was used as the navigational tool. It has been shown that concept maps provide a powerful tool for learning and teaching if designed and constructed carefully [7]. This prototype was then used in three studies to investigate the effect of the e-textbook on students' performance and whether the e-textbook increased students' engagement with the material.

Chapter 3

Software Design

Our goal was to build a prototype embodying our vision of a platform independent e-textbook - an e-textbook that does not require additional plug-ins to run on PCs or laptops. In addition, this e-textbook uses JavaScript to implement the interactive elements of its architecture. This prototype concentrates on the graph data structure and associated algorithms, and uses concept maps as a navigation tool. There were two parts to building this prototype: the technical part of building and coding the concept maps, pages, and interface, and the content part that included deciding what concepts to include, the definitions, examples, images, and animations.

3.1 Use Cases

3.1.1 Actors

The primary actors (users) for the e-textbook prototype are the students, especially Computer Science students. Students will use the system to gain new knowledge or to improve their understanding of the subject. However, instructors can also be actors (users) of the system. They may use the system as a tool when teaching a class or as an additional reading. In addition, public users who are not students or instructors but are interested in gaining information about the e-textbook subject may also use the system.

Note that the use case diagram presented later only shows the student because a student is the main actor and user that we focused on when building this prototype.

3.1.2 Use Cases Diagram

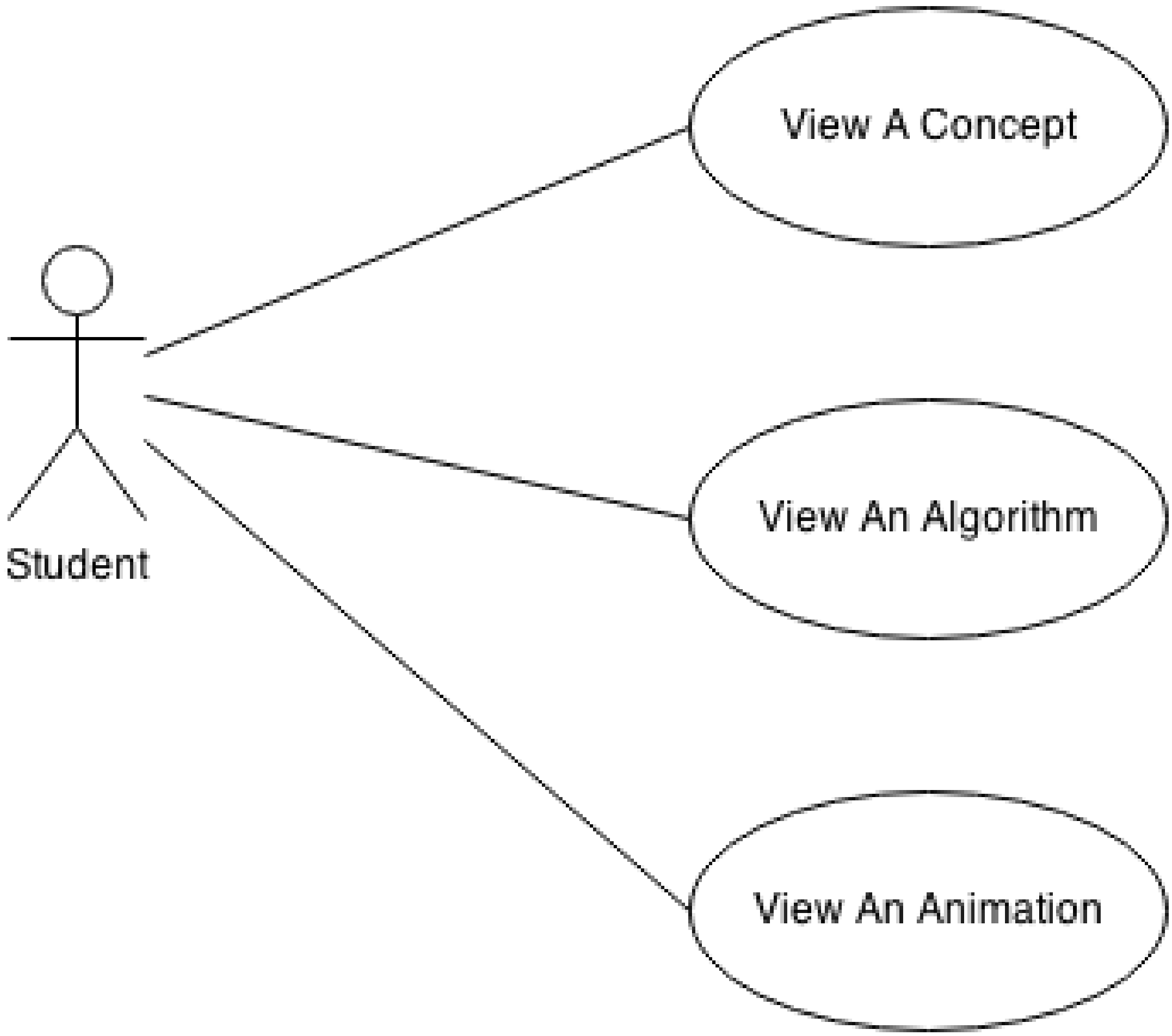

Figure 3.1: Use Cases Diagram

3.1.3 Use Cases

Use case name:	View A Concept
Primary actor:	Student, Instructor, Public Users
Supporting actors:	
Supporting use cases:	
Use case objective:	Displaying a concepts definition and examples
Entry criteria:	
Trigger:	The user clicks on a concepts node in the map
Basic Flow:	The student clicks on a node in the map. Then the definition and examples are loaded and displayed.
Success exit criteria:	The definition and examples have been displayed
Alternate Flow:	
Failure exit criteria:	
Notes:	

Table 3.1: View A Concept Use Case

Use case name	View An Algorithm
Primary actor	Student, Instructor, Public Users
Supporting actors	
Supporting use cases	View A Concept
Use case objective	Displaying a concepts algorithm
Entry criteria	The clicked concept has an associated algorithm
Trigger	The user clicks on a concepts node in the map
Basic Flow	The student clicks on a node in the map. Then the student selects the algorithm. After that, the algorithm is loaded and displayed.
Success exit criteria	The algorithm has been displayed
Alternate Flow	
Failure exit criteria	
Notes	

Table 3.2: View An Algorithm Use Case

Use case name:	View An Animation
Primary actor:	Student, Instructor, Public Users
Supporting actors:	
Supporting use cases:	View A Concept
Use case objective:	Opening a concepts animation
Entry criteria:	The clicked concept has an associated animation
Trigger:	The user clicks on a concepts node in the map
Basic Flow:	The student clicks on a node in the map. Then the student selects the animation. After that, an animation is loaded and displayed
Success exit criteria:	The animation has been displayed
Alternate Flow:	
Failure exit criteria:	
Notes:	

Table 3.3: View An Animation Use Case

3.2 Software Architecture

The main feature of the prototype e-textbook is the navigational concept map. However, unlike the concept maps in CoMPASS [8], which were developed as Java Applets and required plug-ins from users browsers, we wanted our system to be platform independent, able to run on laptops as well as tablet devices, and not require any additional plug-ins from users. These requirements steered us toward the use of HTML5 and JavaScript.

One of the first libraries that we experimented with was SipcyNodes[1]. This library provides a nice interface and smooth animations, and uses XML to store the nodes' information. However, the library has one major drawback and that is the Flash elements used for animation. This drawback not only makes it hard to configure and customize the map as we needed, but it also does not meet our main requirement of not needing a plug-in to run the interface.

One other tool that we looked into was CmapTools[2]. CmapTools is a software for creating concept maps and sharing them. It has great features to control the appearance of the map, the links, and the labels. In addition, it allows linking the concepts to external resources and other created concept maps. The problem with the maps created with this

[1]http://www.spicynodes.org/
[2]http://cmap.ihmc.us/

tool is that they are static and would require another library to read them (using XML files or other extensions that are supported with CmapTools). This meant that we would need to create a library specifically to read those files and configure them to the way we want our concept maps to look like. We did not go with this approach because we wanted the process of creating concept maps to be easy for authors and developers. We did not want them to have to deal with using multiple tools just to create a single concept map.

After experimenting with many options and many JavaScript libraries, we decided to use the D3[3] (Data-Driven Documents) library. D3 is a JavaScript library that has the capabilities to visualize data using HTML, CSS, and SVG. D3 meets our requirements of not requiring any plug-ins, being platform independent, and the ability to run on laptops as well as tablet devices. In addition, the library is flexible, easy to configure and customize to function as we desire. D3 requires the data to be written and stored in JSON files. It then reads these files and produce the concept maps as configured by the author.

Using this approach means that all work is done at the server-side and that browser at the client-side is only responsible for interpreting and displaying the HTML files. Figure 3.2 shows the architecture of the system.

3.3 Object Descriptions

As stated in the previous section, D3 uses JSON to store the concept maps data. The data is stored into objects, namely: nodes and links. Below we provide a detailed description of each of these objects and their attributes (Tables 3.4, 3.5, 3.6). Note that each JSON file i.e. each map is also considered an object that contains other objects.

[3] http://d3js.org/

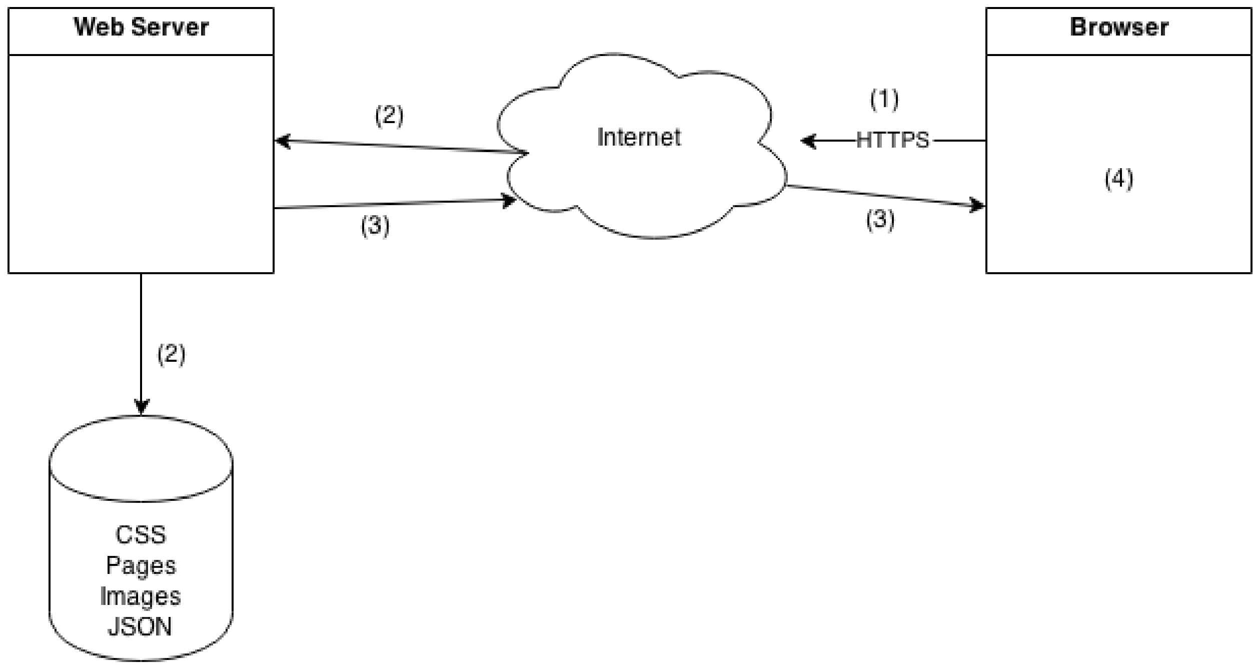

Figure 3.2: Software Architecture

Class Name: Map	
Brief Description: The Map class is responsible for creating concept maps. It holds Node objects and Link objects together.	
Attributes (fields)	Attributes Description
Name	This is the name of the map to be referenced on the program.

Table 3.4: Map Object Description

Class Name: Node	
Brief Description: The Node class is responsible for storing information about each concept on the domain knowledge.	
Attributes (fields)	Attributes Description
Name	This is the name of the concept.
Color	This is the color of the concepts node.
Content	This is the name of the HTML page that contains the concepts definition and examples.
X	This is the x-coordinate of the concepts circle center.
Y	This is the y-coordinate of the concepts circle center.
Fixed	This is a flag that indicates whether the position of the concepts circle is fixed or not.
Size	This is the size of the concepts circle radius.
Algorithm	This is the name of the HTML page that contains the concepts algorithm.
Animation	This is the link of the HTML page that contains the concepts animation.

Table 3.5: Node Object Description

Class Name: Link	
Brief Description: The Link class is responsible for connecting two objects of Node class together	
Attributes (fields)	Attributes Description
Source	This is the starting concept.
Target	This is the ending concept

Table 3.6: Link Object Description

3.4 Object Collaborations

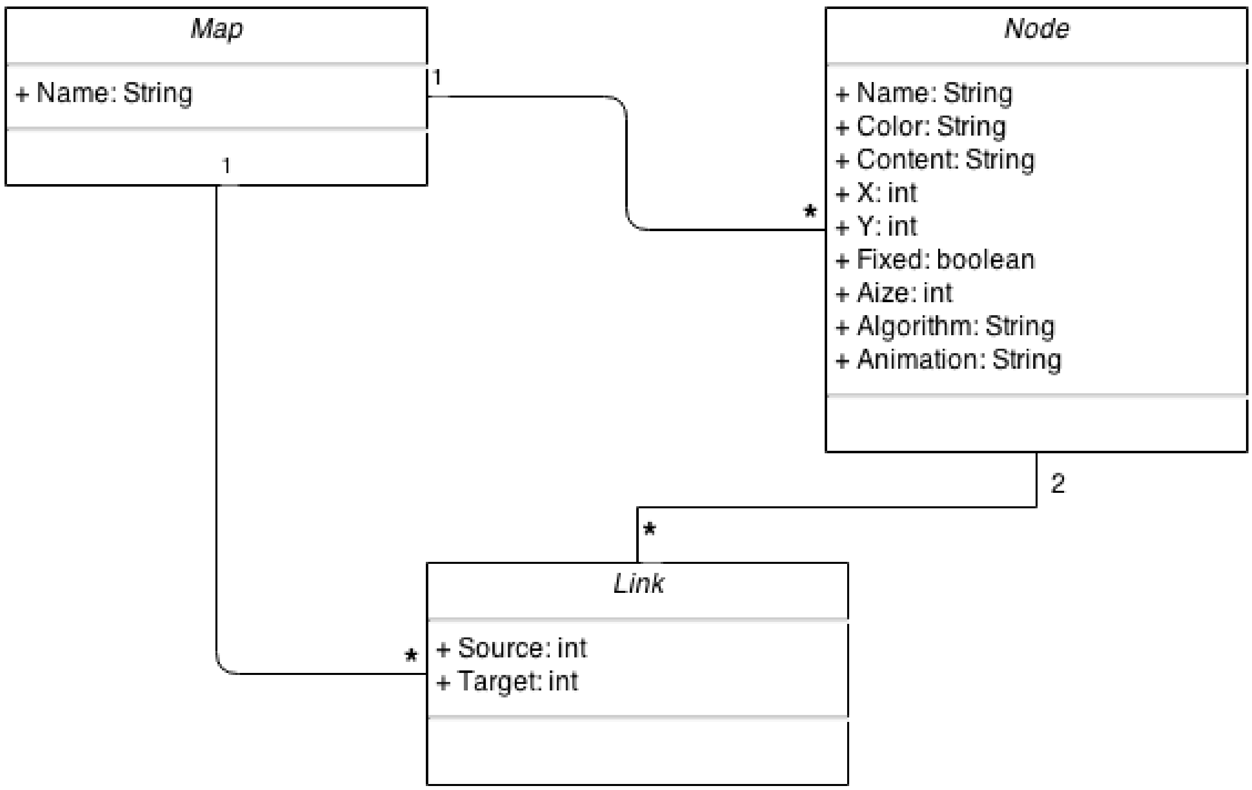

Figure 3.3: Class Diagram

3.5 Human Interface Design

3.5.1 Overview of User Interface

The e-textbooks interface was developed entirely through HTML5 and CSS3. The interface was kept simple so that a student's attention is focused and finding the needed information is easy. The screen is split into three parts: the navigation bar at the top, the concept map at the left, and the content panel at the right.

The navigation bar contains links to the home page, about page, help page, and contact page.

The concept map on the left is color coded to show three different levels. The first level is the central node or concept (which is the concept that is being viewed by the student at any moment). The second level is the nodes or concepts coming out of the central node or concept, and the third level is the node or concept that gets the student to the previous page. When a student clicks on a concept, the system can behave in two different ways. The system either loads a new page with a new concept map, or the clicked concepts node changes size (gets bigger) and the concepts definition and examples are loaded on the right panel.

The content panel on the right shows the information requested by the user, such as the concepts definition, examples, and algorithms. However, the user can navigate or jump from one concept to another through the content panel by clicking on the links available on the displayed text. Each concept on the content area is a link that can be clicked and upon clicking this link, the system will behave in a similar manner as if the user clicked on a concept on the map. The system will either load a new page with a new concept map with the clicked concept in focus, or if the clicked concept is on the same map, then its node will get bigger while the previous concept's node will return to its original size and its definition will be displayed on the right panel.

In addition, the content panel has a menu icon on the upper right that can be clicked to view the side menu. The side menu has several links to additional information about a concept, like algorithms, animations, exercises, and videos. These links will either load the information on the content panel or will direct the user to an external page that contains the required information.

3.5.2 Screen Images

Below are some screen shots (Figures 3.4, 3.5, 3.6) highlighting different features of the e-textbook. To see more screen shots, refer to appendix A.

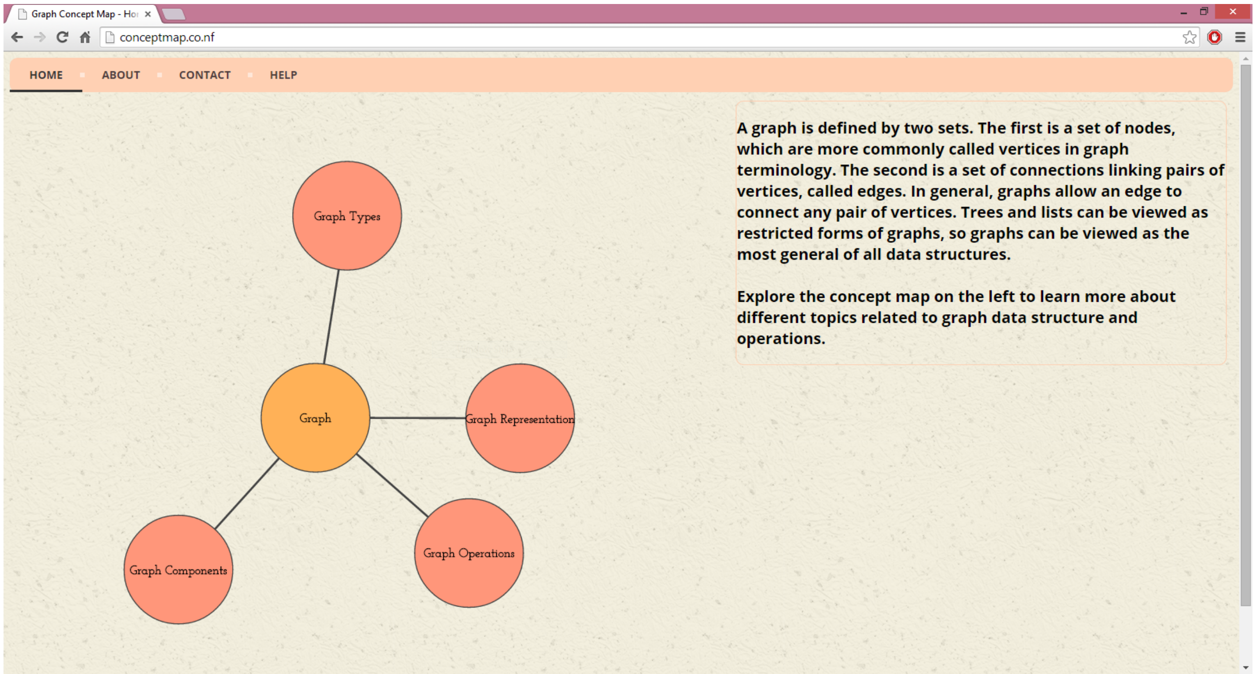

Figure 3.4: E-Textbook Main Page

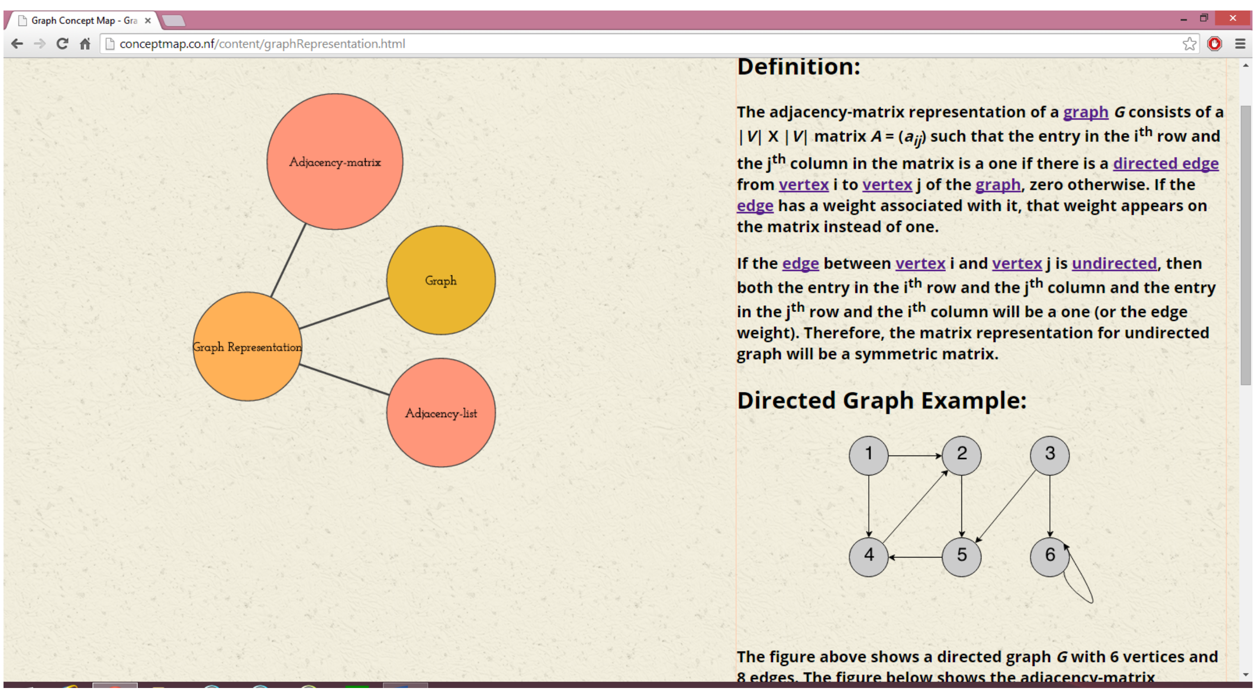

Figure 3.5: E-Textbook's Concept's Definition and Example

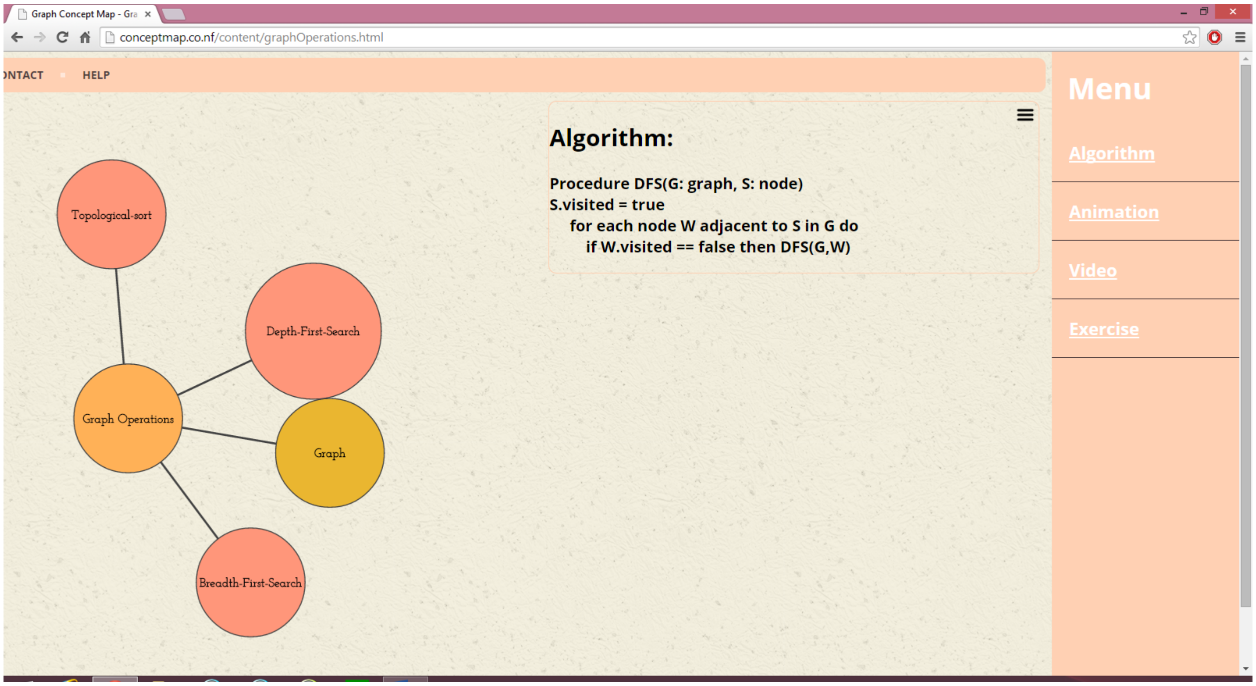

Figure 3.6: E-Textbook's Side Menu

Chapter 4

Methodology

This study focused on the following questions:

- Does an e-textbook improve a student's learning as measured by his/her performance in a test?
- Does an e-textbook improve a student's learning and performance better than a printed textbook?
- Do students like interacting with the interface of an e-textbook and does it increase a student's engagement with the course material?

To answer the first question, a paired t-test was performed to determine if there is a significance difference between students' performance on a test after they used the e-textbook compared to their performance on a test before they used the e-textbook.

The second question is answered by performing an independent t-test to determine if there is a significance difference of performance on a test between students who used the e-textbook compared to students who used a printed textbook.

An interface evaluation survey was used to answer the third question. The survey questions explored the students' reaction to the e-textbook's interface, the layout and organization of its screen, if it is easy to use or not, and if the e-textbook's content helped them understand the subject in a better way than a printed textbook.

To recruit participants for this study, an email flyer was sent to the mailing lists of the undergraduate students and graduate students of the Computer Science and Software Engineering (CSSE) Department at Auburn University. The email flyer contained a set of demographic questions that students had to answer and email their answers back to set a time for them to do the study. The demographic survey asked about student's school year, GPA range, and if the student have any previous knowledge about graph data structure. See appendix B for the email flyer, demographic data questionnaire, and the consent form. Appendix D summarizes the collected demographic data.

However, due to the difficulty of assigning students to the different groups on a matched basis, the students were assigned to these groups randomly. One final note to point out is that the content material covered in this study was the graph data structure.

To test our e-textbook and answer our research questions, we first performed a usability testing. After that, we did a pilot test, and lastly we performed the actual testing. We explain each of these tests and the purpose of each one of them in the following sections.

4.1 Usability Testing

Before testing the usefulness of the e-textbook, a usability testing was done to evaluate the e-textbook's interface. The test was completed by four graduate students who work in the field of Human Computer Interaction (HCI). The participants were asked to come to the lab at a scheduled time, then they were given the consent form to sign and the procedure was explained to them. They had the opportunity to ask any questions they had before they started.

The participants were given a set of 27 questions and were asked to find the answers to these questions using the e-textbook. The usability testing was done using the Concurrent Think Aloud technique [11] in which the participants were asked and encouraged to say their thoughts aloud while they were using the system. Their thoughts and notes were recorded by the observer along with the observer's notes on how the participants used and interacted with the system. In addition, log files that contain the pages each participant visited and the concepts he/she viewed were recorded and stored.

All data collected from this test can be found in appendix C. We discuss the results of this testing in the next chapter.

4.2 Pilot Testing

Before starting the actual testing, we ran a pilot test to make certain that no problems would occur when we did the actual test and to decide the time that should be allocated for each task of the procedure.

Four undergraduate students did the pilot test. Participants came to the lab at the scheduled time, signed the consent form, and the procedure was explained to them. Any questions they had were answered before they started.

The pilot test was composed of four tasks: a pretest, a time to explore the e-textbook and study its material, a posttest, and a survey to evaluate the e-textbook. Both the pretest and the posttest consisted of 20 questions.

The observer recorded the time each participant spent on each of these tasks.

4.3 Actual Testing

For the actual testing, we had 31 participants. Those participants were divided to two groups: undergraduate students (n = 21) and graduate students (n = 10). The undergraduate students were further divided to two groups: students who have previous knowledge of the graph data structure (Students who took or are taking COMP 3270), and students who have little previous knowledge.

The actual testing followed the same procedure as the pilot testing with one exception. The tasks on the actual testing are timed unlike the pilot testing. Those times are based on the times recorded from the pilot testing.

The undergraduate students were randomly assigned to one of two groups: the e-textbook group, or the printed text group. The undergraduate students e-textbook group had a total of 11 participants while the undergraduate students printed text group had a total of 10 participants.

The graduate students were also randomly assigned to one of those two groups. The graduate students e-textbook group had a total of 5 participants and the graduate students printed text group had a total of 5 participants.

The procedure consisted of taking a pretest (time limited to 15 minutes), studying from an e-textbook or a printed text (time limited to 30 minutes), and a posttest (time limited to 15 minutes). Participants on the e-textbook group also answered the interface evaluation survey's questions (no time limit).

Before starting the study, students were handed the consent forms to read and sign, and the study was explained to them. Any questions and concerns they had were answered before they started.

Data collected from this test consisted of pretest scores, posttest score, improvement (posttest score - pretest score) scores, answers to the survey questions, and log files containing visited pages and concepts viewed by each participant.

In this document, we will call undergraduate students who have previous knowledge of graph data structure as 3270 COMP students, and undergraduate students who have little previous knowledge of graph data structure as other UG students. When referring to both of these groups, we will use the term undergraduate students.

The following statistical analysis tests were performed in this study: paired t-test and independent t-test.

The paired t-test was used to determine if the performance of students in the e-textbook group (treatment group) improved after the students used the e-textbook. This test helped us answer our first research question.

The following hypotheses were tested:

Hypothesis Test 1:

There is no difference in the mean scores between the posttest and the pretest of 3270 COMP students in the e-textbook group vs. the posttest mean score for 3270 COMP students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre},\ H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of 3270 COMP students in the e-textbook group

pre = pretest mean score of 3270 COMP students in the e-textbook group

Hypothesis Test 2:

There is no difference in the mean scores between the posttest and the pretest of other UG students in the e-textbook group vs. the posttest mean score for other UG students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre},\ H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of other UG students in the e-textbook group

pre = pretest mean score of other UG students in the e-textbook group

Hypothesis Test 3:

There is no difference in the mean scores between the posttest and the pretest of all undergraduate students in the e-textbook group vs. the posttest mean score for all undergraduate students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre},\ H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of undergraduate students in the e-textbook group

pre = pretest mean score of undergraduate students in the e-textbook group

Hypothesis Test 4:

There is no difference in the mean scores between the posttest and the pretest of graduate students in the e-textbook group vs. the posttest mean score for graduate students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre},\ H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of graduate students in the e-textbook group

pre = pretest mean score of graduate students in the e-textbook group

To answer the second research question, an independent t-test was performed. This test was used to determine if the performance of students in the e-textbook group (treatment group) was better than that of students in the printed textbook. To compare student performance, we first compared the pretest scores of each group of students to ensure that they had similar prior knowledge coming into the experiment (i.e., that the null hypotheses were supported). Then we compared their posttest scores to see if the e-textbook group learned and performed better than the text groups. A comparison of the improvement scores (posttest score - pretest score) was done for a similar purpose.

The following hypotheses were tested:

Hypothesis Test 5:

There is no difference in the pretest mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed textbook group vs. the pretest mean score for 3270 COMP students in the e-textbook group is different from the pretest mean scores for 3270 COMP students in the printed textbook group.

$$H_0\text{: } \mu_{epre} = \mu_{pre},\ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of 3270 COMP students in the e-textbook group

pre = pretest mean score of 3270 COMP students in the printed textbook group

Hypothesis Test 6:

There is no difference in the pretest mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group vs. the pretest mean score for other UG students in the e-textbook group is different from the pretest mean scores for other UG students in the printed textbook group

$$H_0\text{: } \mu_{epre} = \mu_{pre}, \ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of other UG students in the e-textbook group

pre = pretest mean score of other UG students in the printed textbook group

Hypothesis Test 7:

There is no difference in the pretest mean scores of all undergraduate students in the e-textbook group and all undergraduate students in the printed textbook group vs. the pretest mean score for all undergraduate students in the e-textbook group is different from the pretest mean scores for all undergraduate students in the printed textbook group

$$H_0\text{: } \mu_{epre} = \mu_{pre}, \ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of undergraduate students in the e-textbook group

pre = pretest mean score of undergraduate students in the printed textbook group

Hypothesis Test 8:

There is no difference in the pretest mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group vs. the pretest mean score for graduate students in the e-textbook group is different from the pretest mean scores for graduate students in the printed textbook group

$$H_0\text{: } \mu_{epre} = \mu_{pre}, \ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of graduate students in the e-textbook group

pre = pretest mean score of graduate students in the printed textbook group

Hypothesis Test 9:

There is no difference in the posttest mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed textbook group vs. the posttest mean score for 3270 COMP students in the e-textbook group is greater than the posttest mean scores for 3270 COMP students in the printed textbook group.

$$H_0\text{: } \mu_{epost} = \mu_{post},\ H_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of 3270 COMP students in the e-textbook group

post = posttest mean score of 3270 COMP students in the printed textbook group

Hypothesis Test 10:

There is no difference in the posttest mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group vs. the posttest mean score for other UG students in the e-textbook group is greater than the posttest mean scores for other UG students in the printed textbook group.

$$H_0\text{: } \mu_{epost} = \mu_{post},\ H_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of other UG students in the e-textbook group

post = posttest mean score of other UG students in the printed textbook group

Hypothesis Test 11:

There is no difference in the posttest mean scores of all undergraduate students in the e-textbook group and all undergraduate students in the printed textbook group vs. the posttest mean score for all undergraduate students in the e-textbook group is greater than the posttest mean scores for all undergraduate students in the printed textbook group

$$H_0\text{: } \mu_{epost} = \mu_{post},\ H_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of undergraduate students in the e-textbook group

post = posttest mean score of undergraduate students in the printed textbook group

Hypothesis Test 12:

There is no difference in the posttest mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group vs. the posttest mean score for graduate students in the e-textbook group is greater than the posttest mean scores for graduate students in the printed textbook group

$$H_0: \mu_{epost} = \mu_{post},\ H_A: \mu_{epost} > \mu_{post}$$

epost = posttest mean score of graduate students in the e-textbook group

post = posttest mean score of graduate students in the printed textbook group

Hypothesis Test 13:

There is no difference in the improvement mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed textbook group vs. the improvement mean score for 3270 COMP students in the e-textbook group is greater than the improvement mean scores for 3270 COMP students in the printed textbook group.

$$H_0: \mu_{EI} = \mu_{PI},\ H_A: \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of 3270 COMP students in the e-textbook group

PI = improvement mean score of 3270 COMP students in the printed textbook group

Hypothesis Test 14:

There is no difference in the improvement mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group vs. the improvement mean score for other UG students in the e-textbook group is greater than the improvement mean scores for other UG students in the printed textbook group.

$$H_0: \mu_{EI} = \mu_{PI},\ H_A: \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of other UG students in the e-textbook group

PI = improvement mean score of other UG students in the printed textbook group

Hypothesis Test 15:

There is no difference in the improvement mean scores of all undergraduate students in the e-textbook group and all undergraduate students in the printed textbook group vs. the improvement mean score for all undergraduate students in the e-textbook group is greater than the improvement mean scores for all undergraduate students in the printed textbook group.

$$H_0\text{: } \mu_{EI} = \mu_{PI}, \text{ } H_A\text{: } \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of undergraduate students in the e-textbook group

PI = improvement mean score of undergraduate students in the printed textbook group

Hypothesis Test 16:

There is no difference in the improvement mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group vs. the improvement mean score for graduate students in the e-textbook group is greater than the improvement mean scores for graduate students in the printed textbook group.

$$H_0\text{: } \mu_{EI} = \mu_{PI}, \text{ } H_A\text{: } \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of graduate students in the e-textbook group

PI = improvement mean score of graduate students in the printed textbook group

Data collected from this test can be found in appendix E. We discuss the results of data analyses in the next chapter.

Chapter 5

Data Analysis and Results

5.1 Usability Testing

The aim of the usability testing was to uncover any problems the e-textbooks interface might have. As stated in the previous chapter, participants' notes and their interactions with the system were recorded. These notes were reviewed after the testing to decide what needed to be fixed, if any, before the actual testing. We list below a number of interface changes that were implemented before the actual testing and the reasons for each. To see the full list of the recorded notes, see appendix C.

- Usability testers suggested adding/changing the headings on some graph representation examples. As we thought that this suggestion would make the content more clear and understandable to students, it was taken into account and implemented before the actual testing.

- Usability testers suggested adding the information that the matrix representation for an undirected graph will be a symmetric matrix. As we thought that this suggestion would help students understand the content better, it was taken into account and implemented before the actual testing.

- Usability testers suggested changing the common examples of ancestor and parent concepts to a different example on each concept. As we thought that this suggestion would help students understand each concept better and to differentiate between the two concepts, it was taken into account and implemented before the actual testing.

- Two nodes on two different concept maps had the same name. Usability testers suggested editing the labels of these nodes to remove any confusion a student might have. As we thought that this suggestion would make the content more clear to students, it was taken into account and implemented before the actual testing.

One other suggestion that was mentioned by two testers is that the graph types concept map is cluttered and has a large number of nodes that makes it hard to keep track of all the concepts on it. While this suggestion is valid, it was decided to implement it on the next development iteration of the e-textbook because it is a major change requiring considerable time to develop.

Other suggestions (appendix C) that were not considered for implementation were either invalid or out of the scope of the e-textbook subject materials.

5.1.1 User Interface Evaluation Survey

These are the answers of the usability testing participants to the user interface evaluation survey.

Reaction to the interface:

1. Overall reaction to the interface (terrible - wonderful): see Table 5.1

   Response range: 0 (terrible) - 9 (wonderful)

   Result: Number of responses = 4, Mean = 7.75, Standard deviation = 0.43

Response Values	Response Counts	%
0 (terrible)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	1	25%
8	3	75%
9 (wonderful)	0	0%
Total	4	100%

Table 5.1: Overall reaction to the interface (terrible - wonderful)

2. Overall reaction to the interface (difficult - easy): see Table 5.2

   Response range: 0 (difficult) - 9 (easy)

   Result: Number of responses = 4, Mean = 8.75, Standard deviation = 0.433013

Response Values	Response Counts	%
0 (difficult)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	1	25%
9 (easy)	3	75%
Total	4	100%

Table 5.2: Overall reaction to the interface (difficult - easy)

3. Overall reaction to the interface (frustrating - satisfying): see Table 5.3

   Response range: 0 (frustrating) - 9 (satisfying)

   Result: Number of responses = 4, Mean = 8.5, Standard deviation = 0.866025

Response Values	Response Counts	%
0 (frustrating)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	1	25%
8	0	0%
9 (satisfying)	3	75%
Total	4	100%

Table 5.3: Overall reaction to the interface (frustrating - satisfying)

4. Overall reaction to the interface (dull - stimulating): see Table 5.4

   Response range: 0 (dull) - 9 (stimulating)

   Result: Number of responses = 4, Mean = 8.5, Standard deviation = 0.5

Response Values	Response Counts	%
0 (dull)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	2	50%
9 (stimulating)	2	50%
Total	4	100%

Table 5.4: Overall reaction to the interface (dull - stimulating)

5. Overall reaction to the interface (rigid - flexible): see Table 5.5

   Response range: 0 (rigid) - 9 (flexible)

   Result: Number of responses = 4, Mean = 7.75, Standard deviation = 1.089725

Response Values	Response Counts	%
0 (rigid)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	1	25%
7	0	0%
8	2	50%
9 (flexible)	1	25%
Total	4	100%

Table 5.5: Overall reaction to the interface (rigid - flexible)

Screen:

1. Screen: Overall layout: see Table 5.6

   Response range: 0 (bad) - 9 (good)

   Result: Number of responses = 4, Mean = 8, Standard deviation = 1.224745

Response Values	Response Counts	%
0 (bad)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	1	25%
7	0	0%
8	1	25%
9 (good)	2	50%
Total	4	100%

Table 5.6: Screen: Overall layout

2. Screen: The color scheme: see Table 5.7

   Response range: 0 (bad) - 9 (good)

   Result: Number of responses = 4, Mean = 8, Standard deviation = 0.707107

Response Values	Response Counts	%
0 (bad)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	1	25%
8	2	50%
9 (good)	1	25%
Total	4	100%

Table 5.7: Screen: The color scheme

3. Screen: Font style (size, color...): see Table 5.8

   Response range: 0 (bad) - 9 (good)

   Result: Number of responses = 4, Mean = 8, Standard deviation = 0

Response Values	Response Counts	%
0 (bad)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	4	100%
9 (good)	0	0%
Total	4	100%

Table 5.8: Screen: Font style (size, color...)

4. Screen: Separation/ layout of the information with concept maps on the left and text on the right: see Table 5.9

   Response range: 0 (confusing) - 9 (very clear)

   Result: Number of responses = 4, Mean = 9, Standard deviation = 0

Response Values	Response Counts	%
0 (confusing)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	0	0%
9 (very clear)	4	100%
Total	4	100%

Table 5.9: Screen: Separation/ layout of the information with concept maps on the left and text on the right

5. Screen: Sequence of screens: see Table 5.10

   Response range: 0 (confusing) - 9 (very clear)

   Result: Number of responses = 4, Mean = 7.25, Standard deviation = 0.829156

Response Values	Response Counts	%
0 (confusing)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	1	25%
7	1	25%
8	2	50%
9 (very clear)	0	0%
Total	4	100%

Table 5.10: Screen: Sequence of screens

6. Screen: Use of terms throughout the system: see Table 5.11

   Response range: 0 (inconsistent) - 9 (consistent)

   Result: Number of responses = 4, Mean = 9, Standard deviation = 0

Response Values	Response Counts	%
0 (inconsistent)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	0	0%
9 (consistent)	4	100%
Total	4	100%

Table 5.11: Screen: Use of terms throughout the system

Learning:

1. Learning to use the system: see Table 5.12

   Response range: 0 (difficult) - 9 (easy)

   Result: Number of responses = 4, Mean = 8.75, Standard deviation = 0.433013

Response Values	Response Counts	%
0 (difficult)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	1	25%
9 (easy)	3	75%
Total	4	100%

Table 5.12: Learning to use the system

2. Exploring features by trial and error: see Table 5.13

   Response range: 0 (difficult) - 9 (easy)

   Result: Number of responses = 4, Mean = 8.75, Standard deviation = 0.433013

Response Values	Response Counts	%
0 (difficult)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	0	0%
8	1	25%
9 (easy)	3	75%
Total	4	100%

Table 5.13: Exploring features by trial and error

3. Navigation is straightforward: see Table 5.14

   Response range: 0 (never) - 9 (always)

   Result: Number of responses = 4, Mean = 8.5, Standard deviation = 0.866025

Response Values	Response Counts	%
0 (never)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	1	25%
8	0	0%
9 (always)	3	75%
Total	4	100%

Table 5.14: Navigation is straightforward

4. Help menu item: see Table 5.15

   Response range: 0 (unhelpful) - 9 (helpful)

   Result: Number of responses = 2, Mean = 7.5, Standard deviation = 0.5

Response Values	Response Counts	%
0 (Unhelpful)	0	0%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	0	0%
6	0	0%
7	1	50%
8	1	50%
9 (Helpful)	0	0%
Total	2	100%

Table 5.15: Help menu item

Content:

1. The concept map is helpful in understanding the relationships between graph concepts: see Table 5.16

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	2	50%
Strongly Agree	2	50%
Total	4	100%

Table 5.16: The concept map is helpful in understanding the relationships between graph concepts

2. The concept map is helpful in navigating the system: see Table 5.17

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	2	50%
Strongly Agree	2	50%
Total	4	100%

Table 5.17: The concept map is helpful in navigating the system

3. The information presented is useful: see Table 5.18

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	2	50%
Strongly Agree	2	50%
Total	4	100%

Table 5.18: The information presented is useful

4. The information presented is interesting: see Table 5.19

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	3	75%
Strongly Agree	1	25%
Total	4	100%

Table 5.19: The information presented is interesting

5. The definitions of concepts are clear: see Table 5.20

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	3	75%
Strongly Agree	1	25%
Total	4	100%

Table 5.20: The definitions of concepts are clear

6. The examples helped me understand concepts better: see Table 5.21

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	1	25%
Agree	1	25%
Strongly Agree	2	50%
Total	4	100%

Table 5.21: The examples helped me understand concepts better

7. The animations helped me understand concepts better: see Table 5.22

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	2	67%
Strongly Agree	1	33%
Total	3	100%

Table 5.22: The animations helped me understand concepts better

8. The algorithms helped me understand concepts better: see Table 5.23

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	1	33%
Strongly Agree	2	67%
Total	3	100%

Table 5.23: The algorithms helped me understand concepts better

9. I gained new knowledge about graph data structure and algorithms from the system: see Table 5.24

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	1	25%
Agree	1	25%
Strongly Agree	2	50%
Total	4	100%

Table 5.24: I gained new knowledge about graph data structure and algorithms from the system

10. I think the system helped me understand the concepts better than a textbook: see Table 5.25

Response Values	Response Counts	%
Strongly Disagree	0	0%
Disagree	0	0%
Neutral	0	0%
Agree	2	50%
Strongly Agree	2	50%
Total	4	100%

Table 5.25: I think the system helped me understand the concepts better than a textbook

These results are summarized and discussed at the end of this chapter.

5.2 Actual testing

We divide the data collected from this testing to three parts: the pretest, posttest and improvement scores, the user interface evaluation surveys answers, and the log files of the user interaction with the system. Each part of this data is analyzed separately. We grouped the data as follows for analysis purposes: (1) data from COMP 3270 (Introduction to Algorithms) student participants, (2) data from other CSSE undergraduate (UG) student participants, (3) data from all UG students (combining groups 1 and 2), and (4) data from all CSSE graduate student participants. We discuss their analysis in the next sections.

5.2.1 Pretest, Posttest, and Improvement Scores

The pretest, posttest, and improvement scores are helpful in answering the first two research questions we stated in the previous chapter. Paired t-tests and independent t-tests were performed to statistically analyze these data. We report on the results of these tests below. We discuss these results and findings later on. The maximum possible score on both pre and posttest is 29.

	Mean	Standard deviation
pretest	19.75	4.71
posttest	24.63	2.88

Table 5.26: Hypothesis 1 Paired t-test

Q1. Does an e-textbook improve a student's learning as measured by his/her performance in a test?

Null hypothesis 1 states that there is no difference in the mean scores between the posttest and the pretest of 3270 COMP students in the e-textbook group. The alternative hypothesis states that the posttest mean score for 3270 COMP students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre}\text{, } H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of 3270 COMP students in the e-textbook group

pre = pretest mean score of 3270 COMP students in the e-textbook group

A paired t-test was done on the mean scores of the posttest and pretest of 3270 COMP students in the e-textbook group. The test gave a t-statistical of 4.75 and p-value of 0.002. With p-value and a significance level of $\alpha = 0.05$, we can reject the null hypothesis. There is sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance and the mean pretest performance of 3270 COMP students in the e-textbook group with 95% confidence. See Table 5.26 and Figure 5.1.

Null hypothesis 2 states that there is no difference in the mean scores between the posttest and the pretest of other UG students in the e-textbook group. The alternative hypothesis states that the posttest mean score for other UG students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre}\text{, } H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of other UG students in the e-textbook group

pre = pretest mean score of other UG students in the e-textbook group

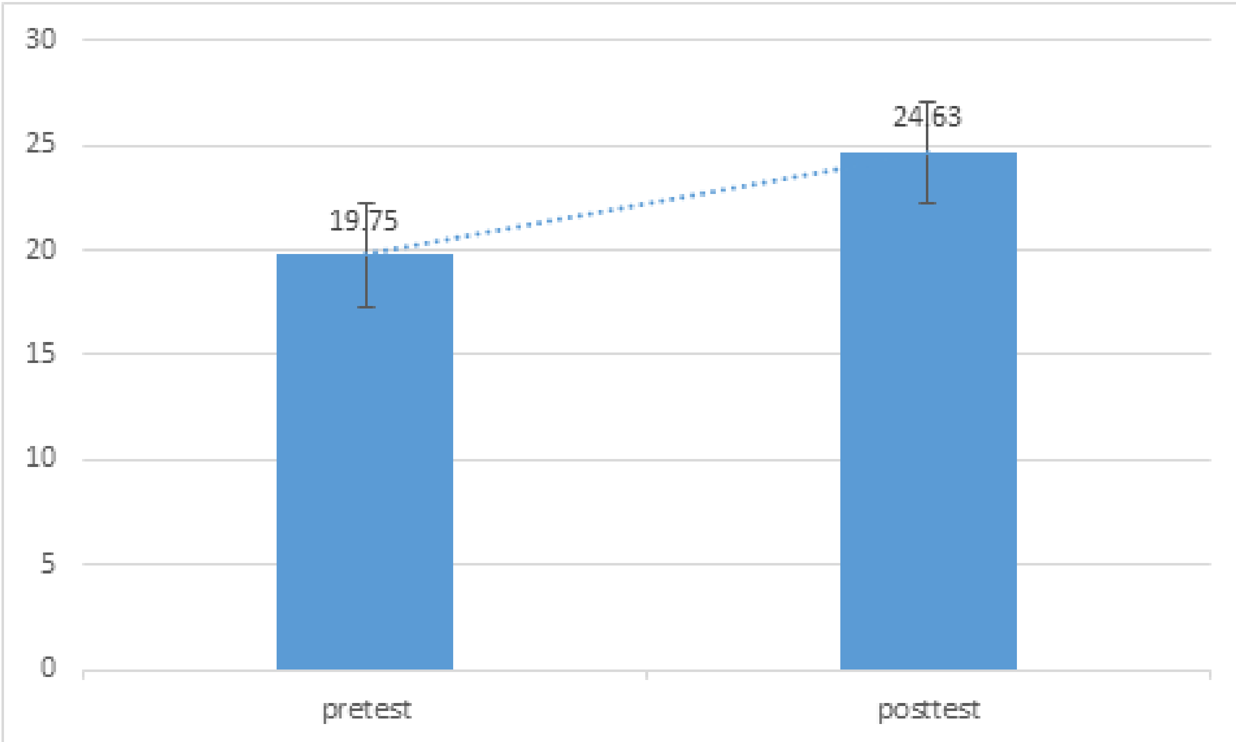

Figure 5.1: Hypothesis 1 Paired t-test

	Mean	Standard deviation
pretest	13.67	4.04
posttest	20.67	5.51

Table 5.27: Hypothesis 2 Paired t-test

A paired t-test was done on the mean scores of the posttest and pretest of other UG students in the e-textbook group. The test gave a t-statistical of 4.58 and p-value of 0.044. With p-value and a significance level of $\alpha = 0.05$, we can reject the null hypothesis. There is sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance and the mean pretest performance of other UG students in the e-textbook group with 95% confidence. See Table 5.27 and Figure 5.2.

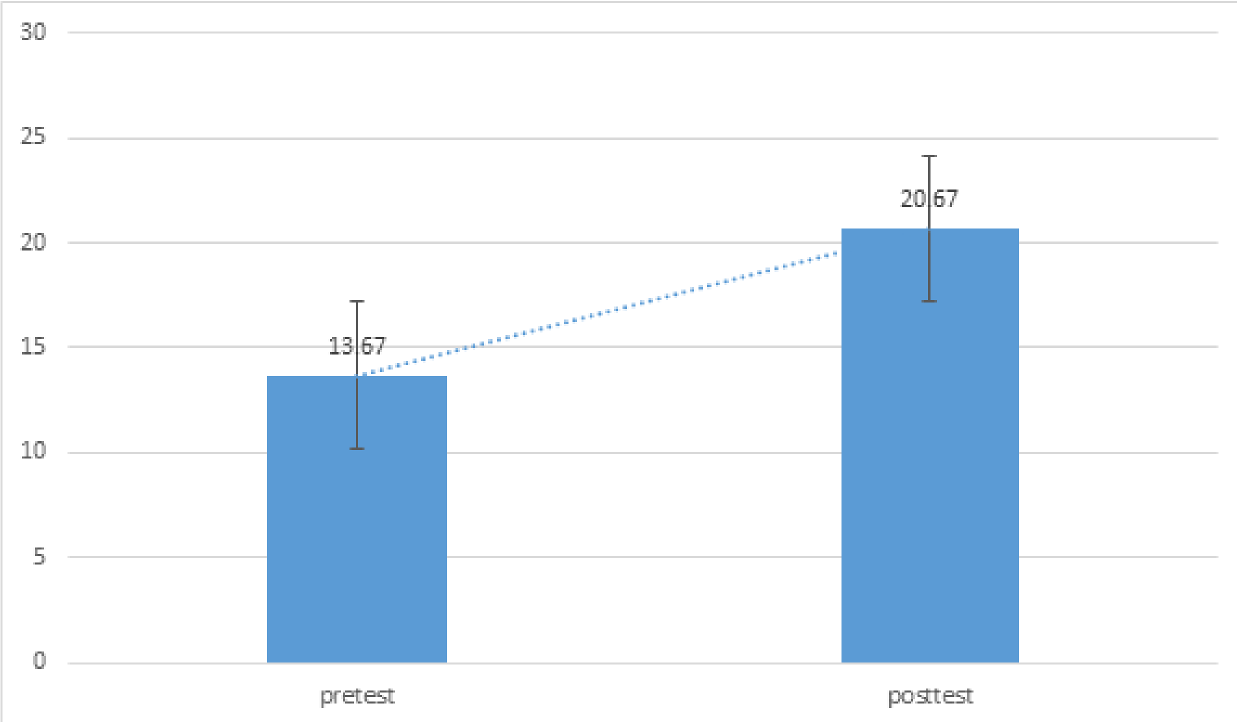

Figure 5.2: Hypothesis 2 Paired t-test

Null hypothesis 3 states that there is no difference in the mean scores between the posttest and the pretest of all undergraduate students in the e-textbook group. The alternative hypothesis states that the posttest mean score for all undergraduate students in the e-textbook group is greater than their pretest mean scores.

$$H_0\text{: } \mu_{post} = \mu_{pre},\ H_A\text{: } \mu_{post} > \mu_{pre}$$

post = posttest mean score of undergraduate students in the e-textbook group

pre = pretest mean score of undergraduate students in the e-textbook group

A paired t-test was done on the mean scores of the posttest and pretest of all undergraduate students in the e-textbook group. The test gave a t-statistical of 6.29 and p-value of 0.000. With p-value and a significance level of $\alpha = 0.05$, we can reject the null hypothesis. There is sufficient evidence to conclude that there was a statistically significant difference

	Mean	Standard deviation
pretest	18.09	5.19
posttest	23.55	3.91

Table 5.28: Hypothesis 3 Paired t-test

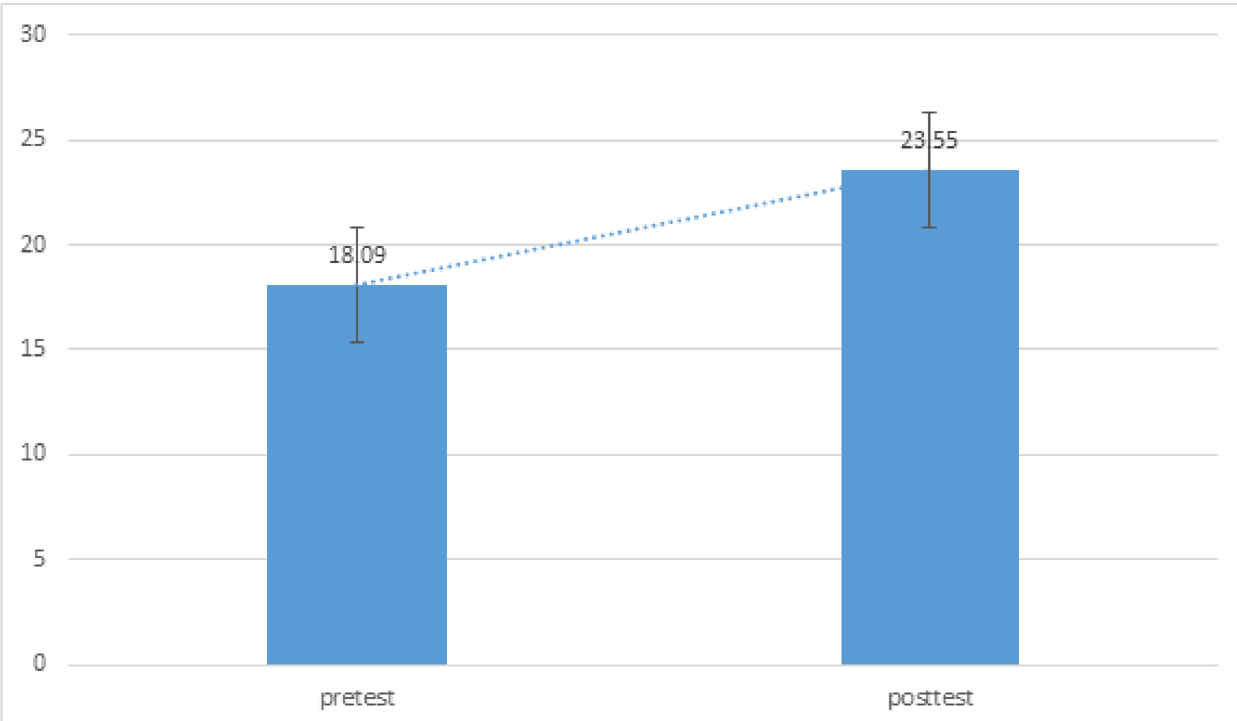

Figure 5.3: Hypothesis 3 Paired t-test

between the mean posttest performance and the mean pretest performance of all undergraduate students in the e-textbook group with 95% confidence. See Table 5.28 and Figure 5.3.

Null hypothesis 4 states that there is no difference in the mean scores between the posttest and the pretest of all graduate students in the e-textbook group. The alternative hypothesis states that the posttest mean score for graduate students in the e-textbook group is greater than their pretest mean scores.

$$H_0\colon \mu_{post} = \mu_{pre},\ H_A\colon \mu_{post} > \mu_{pre}$$

post = posttest mean score of graduate students in the e-textbook group

	Mean	Standard deviation
pretest	23.60	6.11
posttest	25.20	3.56

Table 5.29: Hypothesis 4 Paired t-test

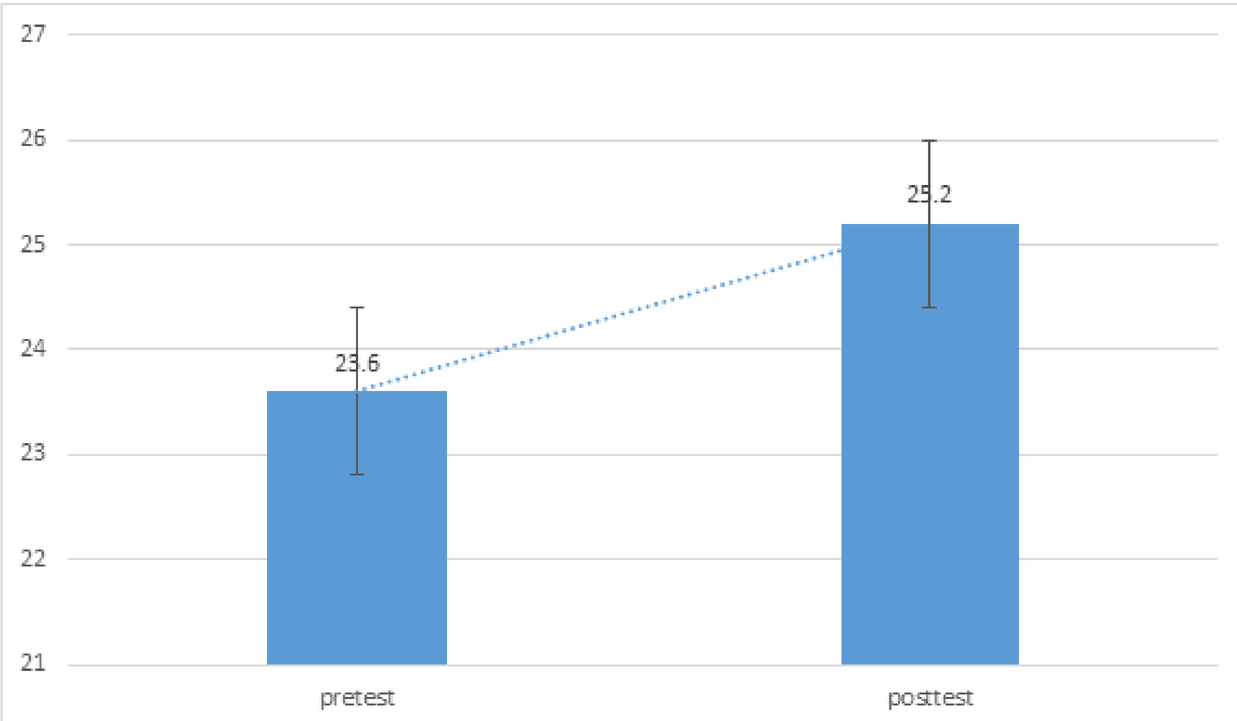

Figure 5.4: Hypothesis 4 Paired t-test

pre = pretest mean score of graduate students in the e-textbook group

A paired t-test was done on the mean scores of the posttest and pretest of graduate students in the e-textbook group. The test gave a t-statistical of 0.93 and p-value of 0.405. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. Therefore, there is not sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance and the mean pretest performance of graduate students in the e-textbook group with 95% confidence. See Table 5.29 and Figure 5.4.

	Mean	Standard deviation
E-textbook Group pretest	19.75	4.71
Printed Textbook Group pretest	20.29	5.71

Table 5.30: Hypothesis 5 Two-sample t-test Assuming Unequal Variances

Q2. Does an e-textbook improve a student's learning and performance better than a printed textbook?

Null hypothesis 5 states that there is no difference in the pretest mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed textbook group. The alternative hypothesis states that the pretest mean score for 3270 COMP students in the e-textbook group is different from the pretest mean scores for 3270 COMP students in the printed textbook group.

$$H_0\text{: } \mu_{epre} = \mu_{pre}\text{, } H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of 3270 COMP students in the e-textbook group

pre = pretest mean score of 3270 COMP students in the printed textbook group

An independent t-test was done on the mean score of the pretest of 3270 COMP students in the e-textbook group and the mean score of the pretest of 3270 COMP students in the printed textbook group. The test gave a t-statistical of -0.20 and p-value of 0.848. With p-value and a significance level of α= 0.05, we fail to reject the null hypothesis. There is sufficient evidence to conclude that there was not a statistically significant difference between the mean pretest performance of 3270 COMP students in the e-textbook group and the mean pretest performance of 3270 COMP students in the printed textbook group with 95% confidence. See Table 5.30 and Figure 5.5.

Null hypothesis 6 states that there is no difference in the pretest mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group. The alternative hypothesis states that the pretest mean score for other UG students in the e-textbook group is different from the pretest mean scores for other UG students in the printed textbook group.

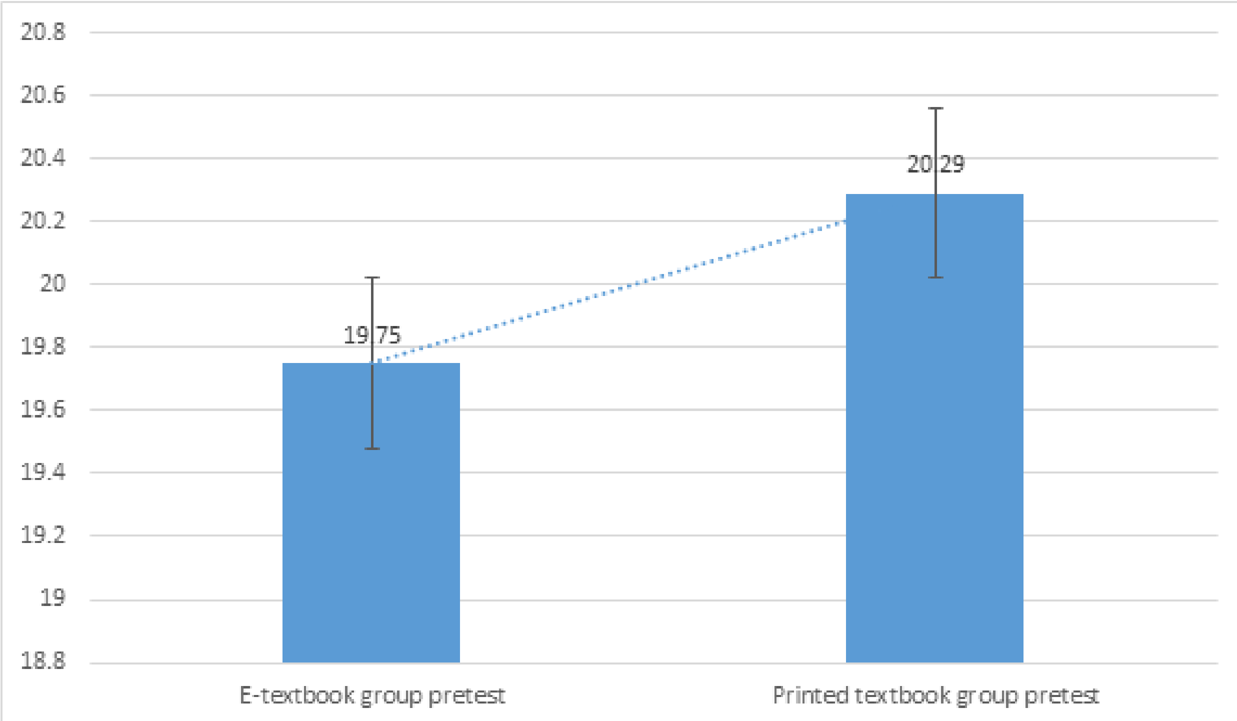

Figure 5.5: Hypothesis 5 Two-sample t-test Assuming Unequal Variances

$$\text{H}_0\text{: } \mu_{epre} = \mu_{pre}, \text{ H}_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of other UG students in the e-textbook group

pre = pretest mean score of other UG students in the printed textbook group

An independent t-test was done on the mean score of the pretest of other UG students in the e-textbook group and the mean score of the pretest of other UG students in the printed textbook group. The test gave a t-statistical of -1.04 and p-value of 0.409. With p-value and a significance level of α= 0.05, we fail to reject the null hypothesis. There is sufficient evidence to conclude that there was not a statistically significant difference between the mean pretest performance of other UG students in the e-textbook group and the mean pretest performance of other UG students in the printed textbook group with 95% confidence. See Table 5.31 and Figure 5.6.

Null hypothesis 7 states that there is no difference in the pretest mean scores of all undergraduate students in the e-textbook group and all undergraduate students in the printed

	Mean	Standard deviation
E-textbook Group pretest	13.67	4.04
Printed Textbook Group pretest	19.00	7.94

Table 5.31: Hypothesis 6 Two-sample t-test Assuming Unequal Variances

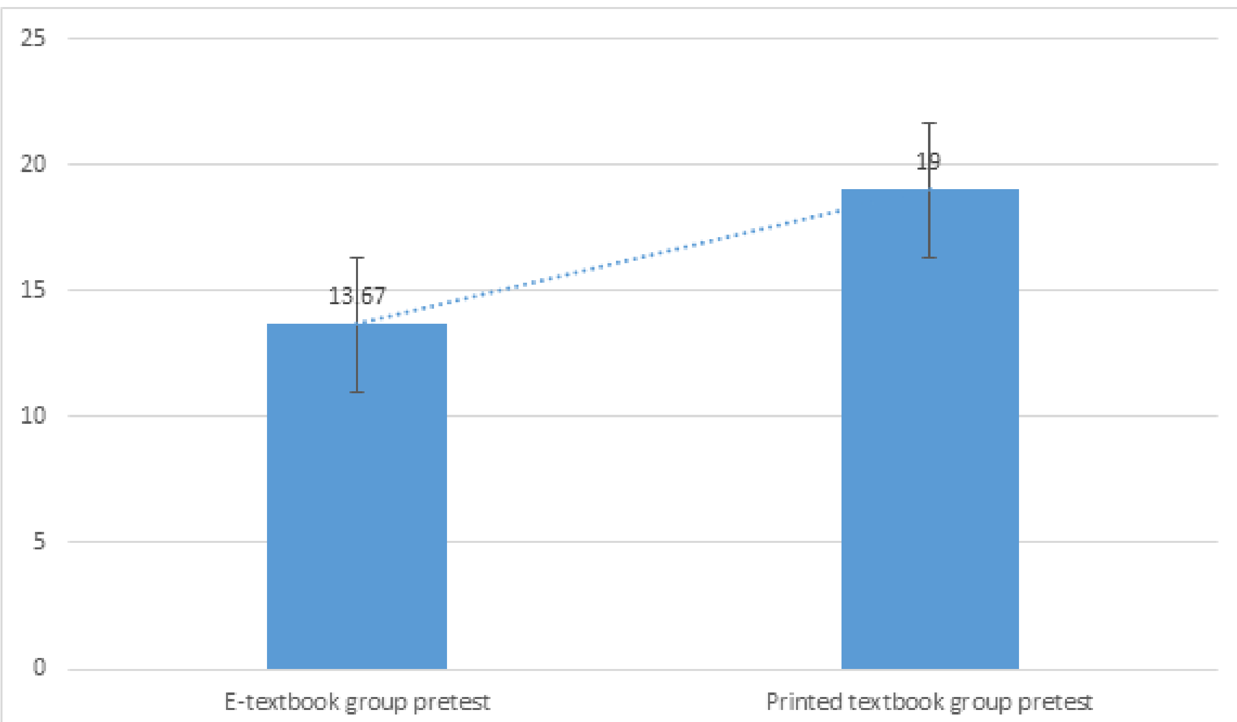

Figure 5.6: Hypothesis 6 Two-sample t-test Assuming Unequal Variances

	Mean	Standard deviation
E-textbook Group pretest	18.09	5.19
Printed Textbook Group pretest	19.90	6.01

Table 5.32: Hypothesis 7 Two-sample t-test Assuming Unequal Variances

textbook group. The alternative hypothesis states that the pretest mean score for undergraduate students in the e-textbook group is different from the pretest mean scores for undergraduate students in the printed textbook group.

$$H_0\text{: } \mu_{epre} = \mu_{pre},\ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of undergraduate students in the e-textbook group

pre = pretest mean score of undergraduate students in the printed textbook group

An independent t-test was done on the mean score of the pretest of undergraduate students in the e-textbook group and the mean score of the pretest of undergraduate students in the printed textbook group. The test gave a t-statistical of -0.74 and p-value of 0.472. With p-value and a significance level of α= 0.05, we fail to reject the null hypothesis. There is sufficient evidence to conclude that there was not a statistically significant difference between the mean pretest performance of undergraduate students in the e-textbook group and the mean pretest performance of undergraduate students in the printed textbook group with 95% confidence. See Table 5.32 and Figure 5.7.

Null hypothesis 8 states that there is no difference in the pretest mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group. The alternative hypothesis states that the pretest mean score for graduate students in the e-textbook group is different from the pretest mean scores for graduate students in the printed textbook group.

$$H_0\text{: } \mu_{epre} = \mu_{pre},\ H_A\text{: } \mu_{epre} \neq \mu_{pre}$$

epre = pretest mean score of graduate students in the e-textbook group

pre = pretest mean score of graduate students in the printed textbook group

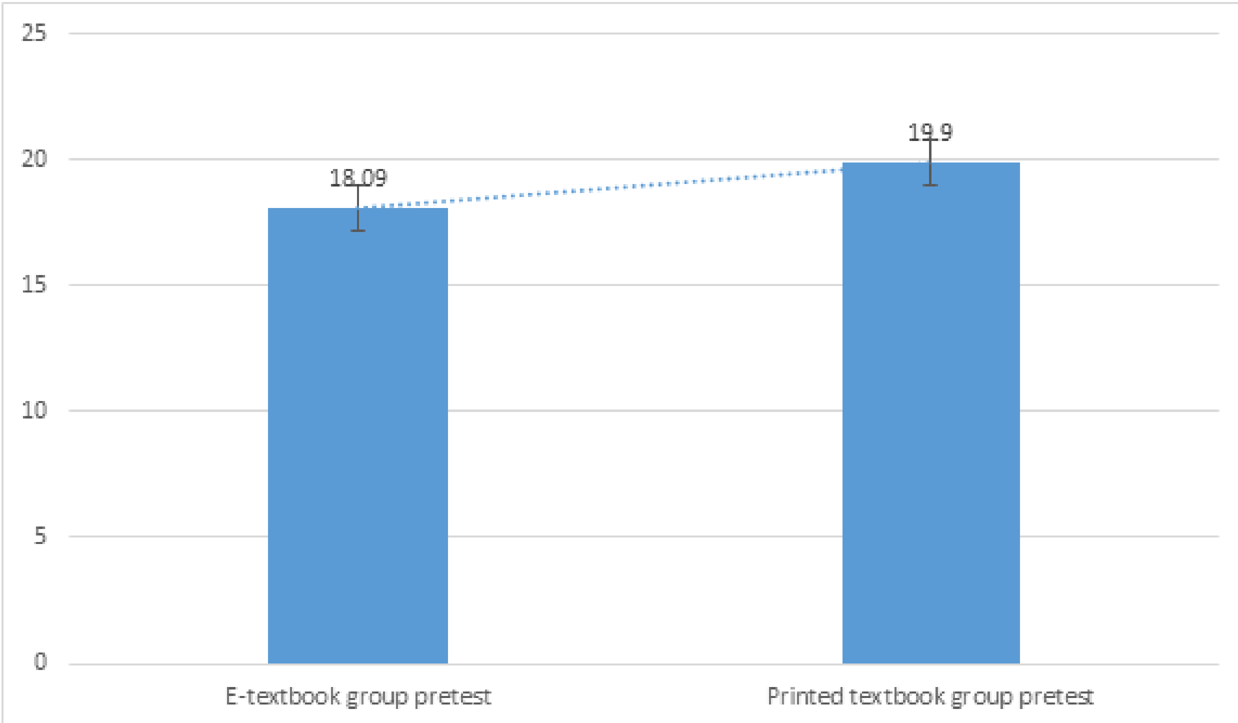

Figure 5.7: Hypothesis 7 Two-sample t-test Assuming Unequal Variances

	Mean	Standard deviation
E-textbook Group pretest	23.60	6.11
Printed Textbook Group pretest	16.40	2.88

Table 5.33: Hypothesis 8 Two-sample t-test Assuming Unequal Variances

An independent t-test was done on the mean score of the pretest of graduate students in the e-textbook group and the mean score of the pretest of graduate students in the printed textbook group. The test gave a t-statistical of 2.38 and p-value of 0.063. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is sufficient evidence to conclude that there was not a statistically significant difference between the mean pretest performance of graduate students in the e-textbook group and the mean pretest performance of graduate students in the printed textbook group with 95% confidence. See Table 5.33 and Figure 5.8.

Null hypothesis 9 states that there is no difference in the posttest mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed textbook

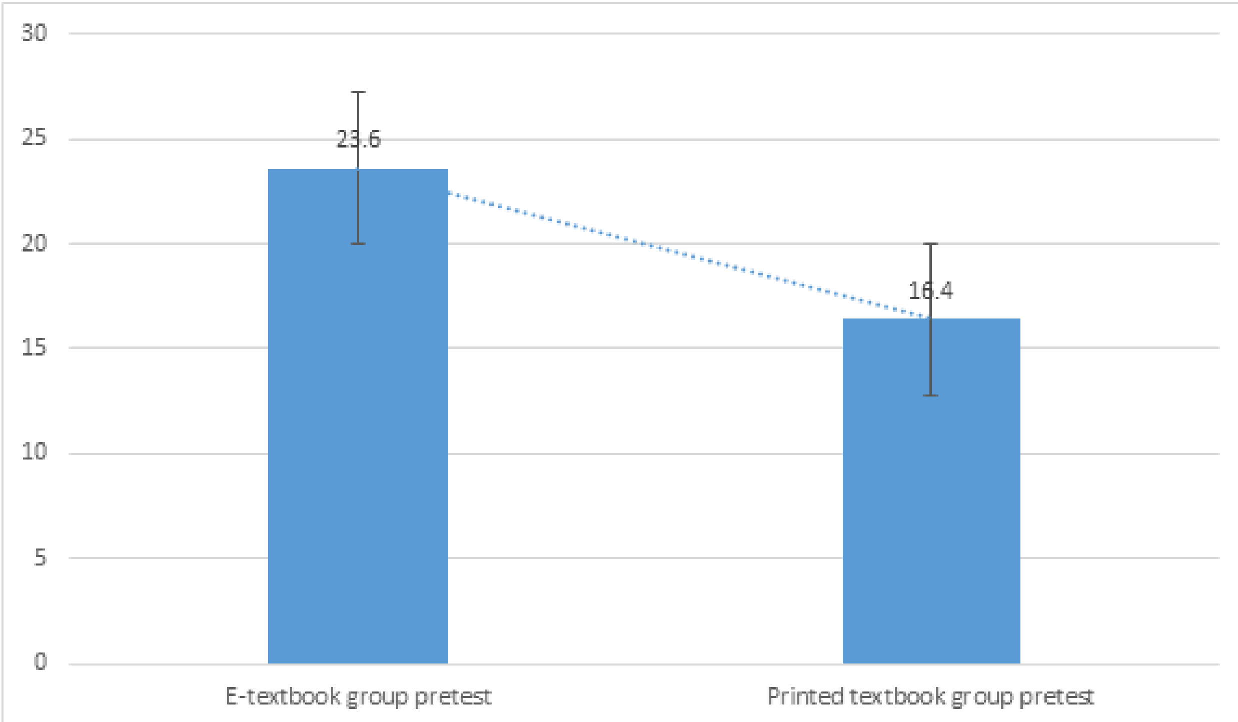

Figure 5.8: Hypothesis 8 Two-sample t-test Assuming Unequal Variances

group. The alternative hypothesis states that the posttest mean score for 3270 COMP students in the e-textbook group is greater than the posttest mean scores for 3270 COMP students in the printed textbook group.

$$H_0\text{: } \mu_{epost} = \mu_{post},\ H_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of 3270 COMP students in the e-textbook group

post = posttest mean score of 3270 COMP students in the printed textbook group

An independent t-test was done on the mean score of the posttest of 3270 COMP students in the e-textbook group and the mean score of the posttest of 3270 COMP students in the printed textbook group. The test gave a t-statistical of -0.54 and p-value of 0.610. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance of 3270 COMP students in the e-textbook group

	Mean	Standard deviation
E-textbook Group posttest	24.63	2.88
Printed Textbook Group posttest	25.29	1.98

Table 5.34: Hypothesis 9 Two-sample t-test Assuming Unequal Variances

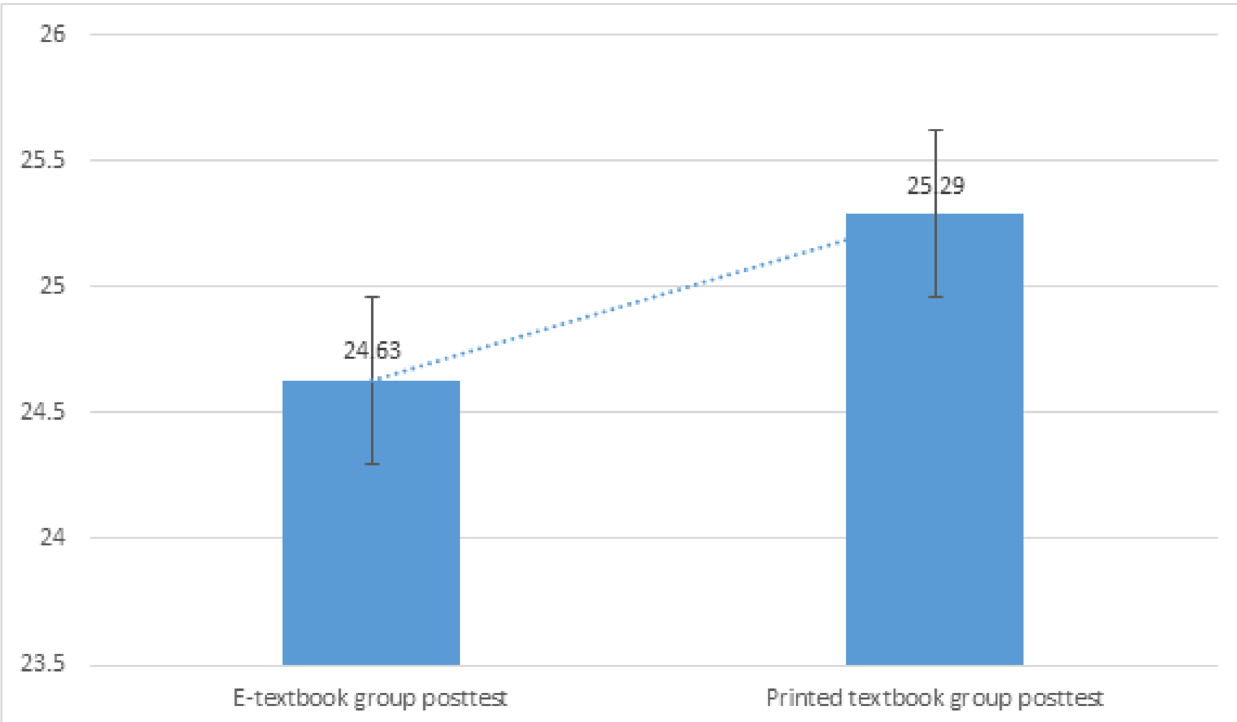

Figure 5.9: Hypothesis 9 Two-sample t-test Assuming Unequal Variances

and the mean posttest performance of 3270 COMP students in the printed textbook group with 95% confidence. See Table 5.34 and Figure 5.9.

Null hypothesis 10 states that there is no difference in the posttest mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group. The alternative hypothesis states that the posttest mean score for other UG students in the e-textbook group is greater than the posttest mean scores for other UG students in the printed textbook group.

$$H_0\text{: } \mu_{epost} = \mu_{post},\ H_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of other UG students in the e-textbook group

post = posttest mean score of other UG students in the printed textbook group

	Mean	Standard deviation
E-textbook Group posttest	20.67	5.51
Printed Textbook Group posttest	23.00	3.61

Table 5.35: Hypothesis 10 Two-sample t-test Assuming Unequal Variances

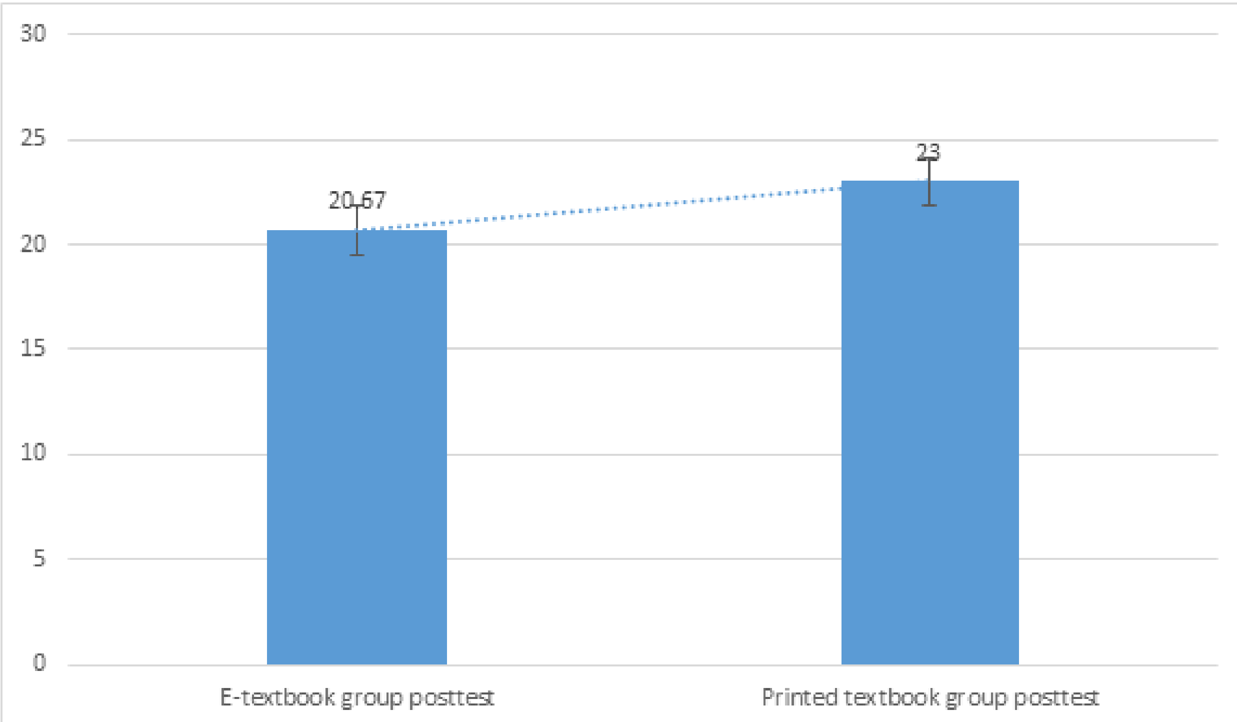

Figure 5.10: Hypothesis 10 Two-sample t-test Assuming Unequal Variances

An independent t-test was done on the mean score of the posttest of other UG students in the e-textbook group and the mean score of the posttest of other UG students in the printed textbook group. The test gave a t-statistical of -0.61 and p-value of 0.583. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance of other UG students in the e-textbook group and the mean posttest performance of other UG students in the printed textbook group with 95% confidence. See Table 5.35 and Figure 5.10.

Null hypothesis 11 states that there is no difference in the posttest mean scores of all undergraduate students in the e-textbook group and all undergraduate students in the

	Mean	Standard deviation
E-textbook Group posttest	23.55	3.91
Printed Textbook Group posttest	24.60	2.59

Table 5.36: Hypothesis 11 Two-sample t-test Assuming Unequal Variances

printed textbook group. The alternative hypothesis states that the posttest mean score for all undergraduate students in the e-textbook group is greater than the posttest mean scores for all undergraduate students in the printed textbook group.

$$\mathrm{H}_0\text{: } \mu_{epost} = \mu_{post},\ \mathrm{H}_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of undergraduate students in the e-textbook group

post = posttest mean score of undergraduate students in the printed textbook group

An independent t-test was done on the mean score of the posttest of all undergraduate students in the e-textbook group and the mean score of the posttest of all undergraduate students in the printed textbook group. The test gave a t-statistical of -0.73 and p-value of 0.472. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance of all undergraduate students in the e-textbook group and the mean posttest performance of all undergraduate students in the printed textbook group with 95% confidence. See Table 5.36 and Figure 5.11.

Null hypothesis 12 states that there is no difference in the posttest mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group. The alternative hypothesis states that the posttest mean score for graduate students in the e-textbook group is greater than the posttest mean scores for graduate students in the printed textbook group.

$$\mathrm{H}_0\text{: } \mu_{epost} = \mu_{post},\ \mathrm{H}_A\text{: } \mu_{epost} > \mu_{post}$$

epost = posttest mean score of graduate students in the e-textbook group

post = posttest mean score of graduate students in the printed textbook group

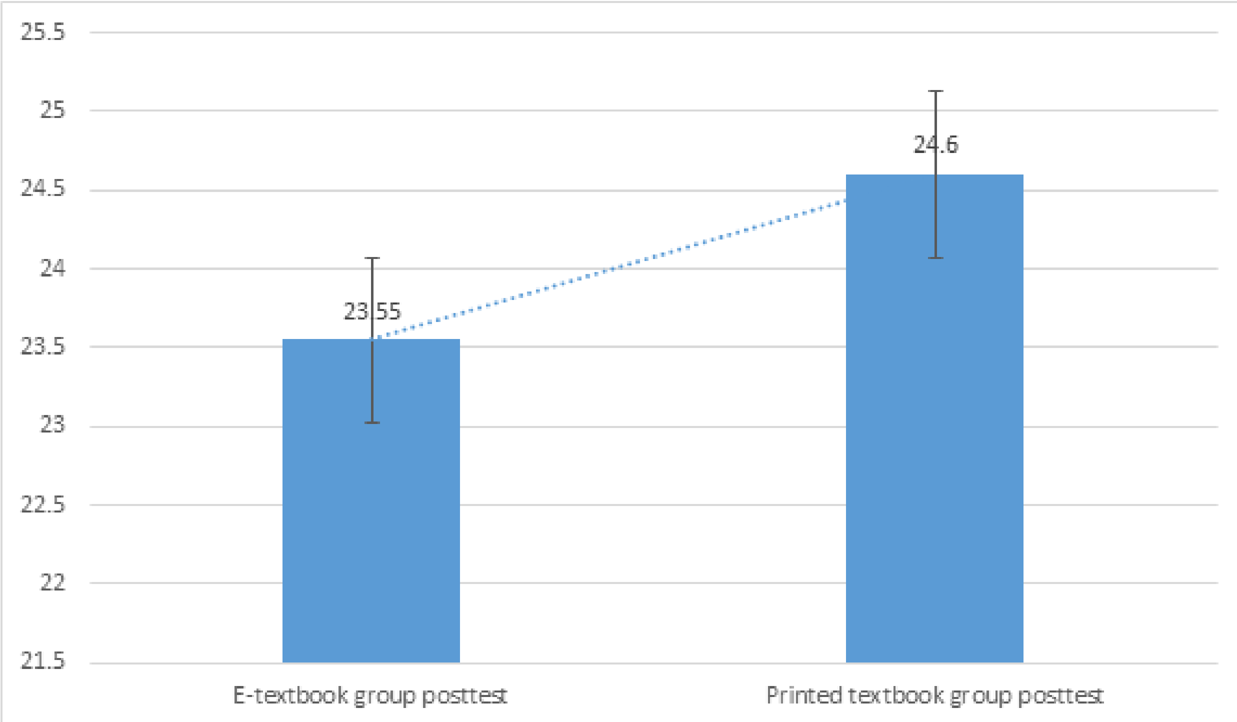

Figure 5.11: Hypothesis 11 Two-sample t-test Assuming Unequal Variances

	Mean	Standard deviation
E-textbook Group posttest	25.20	3.56
Printed Textbook Group posttest	22.80	1.79

Table 5.37: Hypothesis 12 Two-sample t-test Assuming Unequal Variances

An independent t-test was done on the mean score of the posttest of graduate students in the e-textbook group and the mean score of the posttest of graduate students in the printed textbook group. The test gave a t-statistical of 1.35 and p-value of 0.236. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean posttest performance of graduate students in the e-textbook group and the mean posttest performance of graduate students in the printed textbook group with 95% confidence. See Table 5.37 and Figure 5.12.

Null hypothesis 13 states that there is no difference in the improvement mean scores of 3270 COMP students in the e-textbook group and 3270 COMP students in the printed

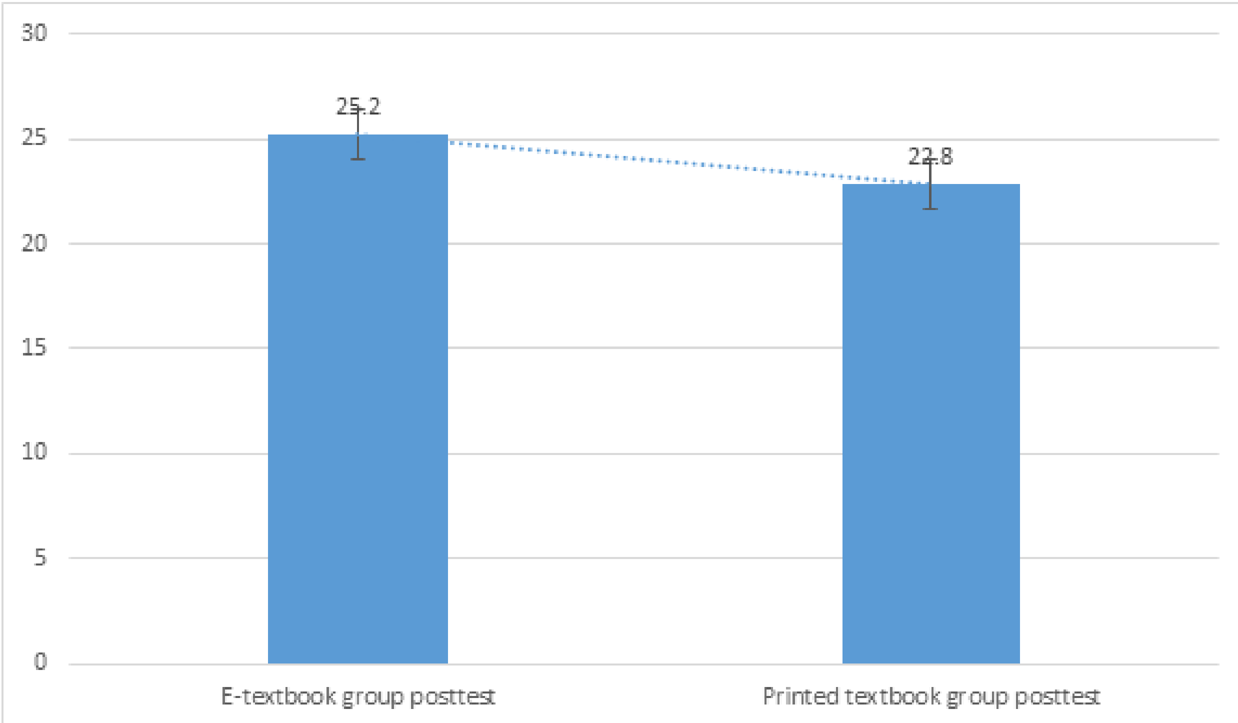

Figure 5.12: Hypothesis 12 Two-sample t-test Assuming Unequal Variances

textbook group. The alternative hypothesis states that the improvement mean score for 3270 COMP students in the e-textbook group is greater than the improvement mean score for 3270 COMP students in the printed textbook group.

$$\text{H}_0\text{: } \mu_{EI} = \mu_{PI}, \text{ H}_A\text{: } \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of 3270 COMP students in the e-textbook group

PI = improvement mean score of 3270 COMP students in the printed textbook group

An independent t-test was done on the mean score of the improvement of 3270 COMP students in the e-textbook group and the mean score of the improvement of 3270 COMP students in the printed textbook group. The test gave a t-statistical of -0.07 and p-value of 0.949. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean improvement of 3270 COMP students in the e-textbook group

	Mean	Standard deviation
E-textbook Group improvement	4.88	2.90
Printed Textbook Group improvement	5.00	4.28

Table 5.38: Hypothesis 13 Two-sample t-test Assuming Unequal Variances

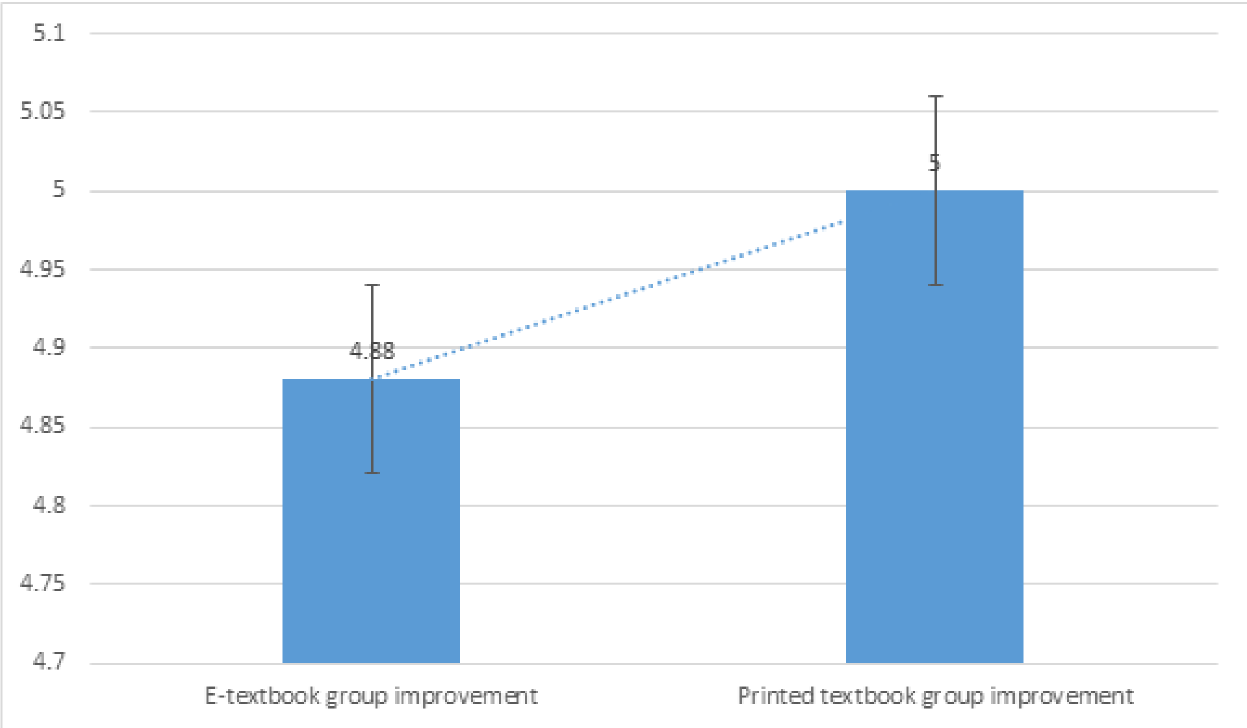

Figure 5.13: Hypothesis 13 Two-sample t-test Assuming Unequal Variances

and the mean improvement of 3270 COMP students in the printed textbook group with 95% confidence. See Table 5.38 and Figure 5.13.

Null hypothesis 14 states that there is no difference in the improvement mean scores of other UG students in the e-textbook group and other UG students in the printed textbook group. The alternative hypothesis states that the improvement mean score for other UG students in the e-textbook group is greater than the improvement mean score for other UG students in the printed textbook group.

$$H_0\text{: } \mu_{EI} = \mu_{PI}\text{, } H_A\text{: } \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of other UG students in the e-textbook group

PI = improvement mean score of other UG students in the printed textbook group

	Mean	Standard deviation
E-textbook Group improvement	7.00	2.65
Printed Textbook Group improvement	4.00	4.36

Table 5.39: Hypothesis 14 Two-sample t-test Assuming Unequal Variances

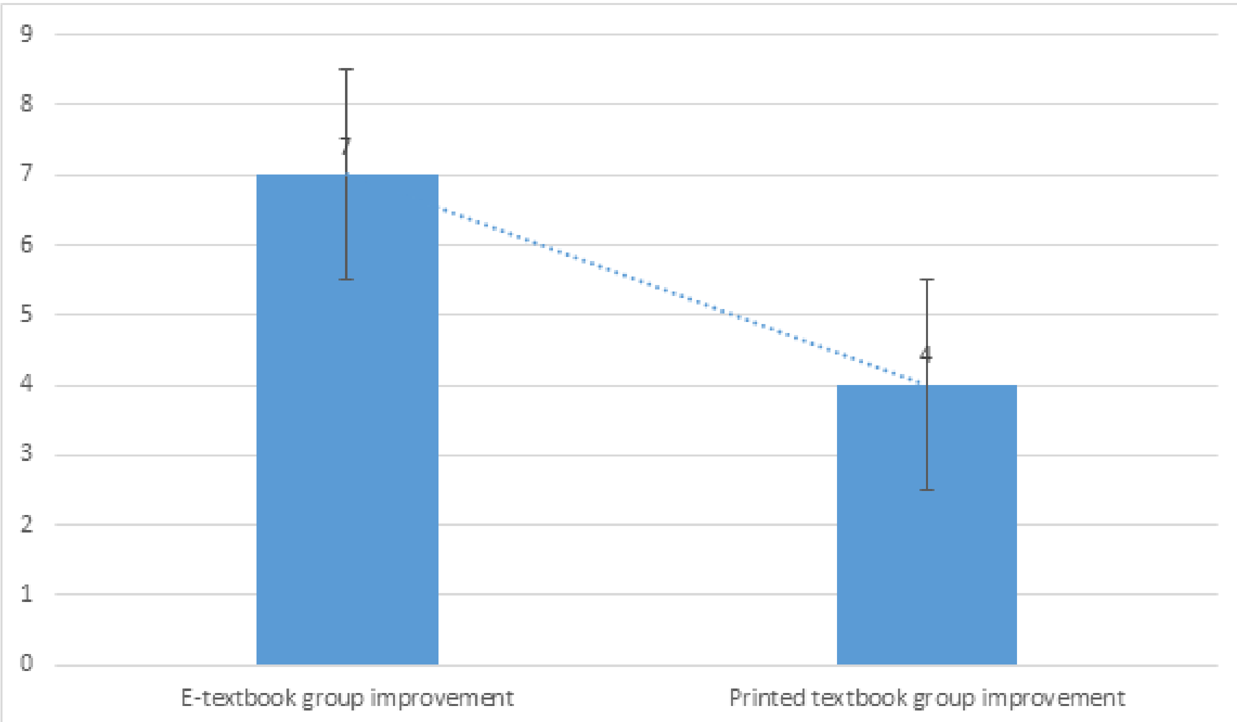

Figure 5.14: Hypothesis 14 Two-sample t-test Assuming Unequal Variances

An independent t-test was done on the mean score of the improvement of other UG students in the e-textbook group and the mean score of the improvement of other UG students in the printed textbook group. The test gave a t-statistical of 1.02 and p-value of 0.383. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean improvement of other UG students in the e-textbook group and the mean improvement of other UG students in the printed textbook group with 95% confidence. See Table 5.39 and Figure 5.14.

Null hypothesis 15 states that there is no difference in the improvement mean scores of all undergraduate students in the e-textbook group and all undergraduate students in

	Mean	Standard deviation
E-textbook Group improvement	5.45	2.88
Printed Textbook Group improvement	4.70	4.08

Table 5.40: Hypothesis 15 Two-sample t-test Assuming Unequal Variances

the printed textbook group. The alternative hypothesis states that the improvement mean score for all undergraduate students in the e-textbook group is greater than the improvement mean score for all undergraduate students in the printed textbook group.

$$H_0: \mu_{EI} = \mu_{PI}, \; H_A: \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of undergraduate students in the e-textbook group

PI = improvement mean score of undergraduate students in the printed textbook group

An independent t-test was done on the mean score of the improvement of all undergraduate students in the e-textbook group and the mean score of the improvement of all undergraduate students in the printed textbook group. The test gave a t-statistical of 0.49 and p-value of 0.634. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean improvement of all undergraduate students in the e-textbook group and the mean improvement of all undergraduate students in the printed textbook group with 95% confidence. See Table 5.40 and Figure 5.15.

Null hypothesis 16 states that there is no difference in the improvement mean scores of graduate students in the e-textbook group and graduate students in the printed textbook group. The alternative hypothesis states that the improvement mean score for graduate students in the e-textbook group is greater than the improvement mean score for graduate students in the printed textbook group.

$$H_0: \mu_{EI} = \mu_{PI}, \; H_A: \mu_{EI} > \mu_{PI}$$

EI = improvement mean score of graduate students in the e-textbook group

PI = improvement mean score of graduate students in the printed textbook group

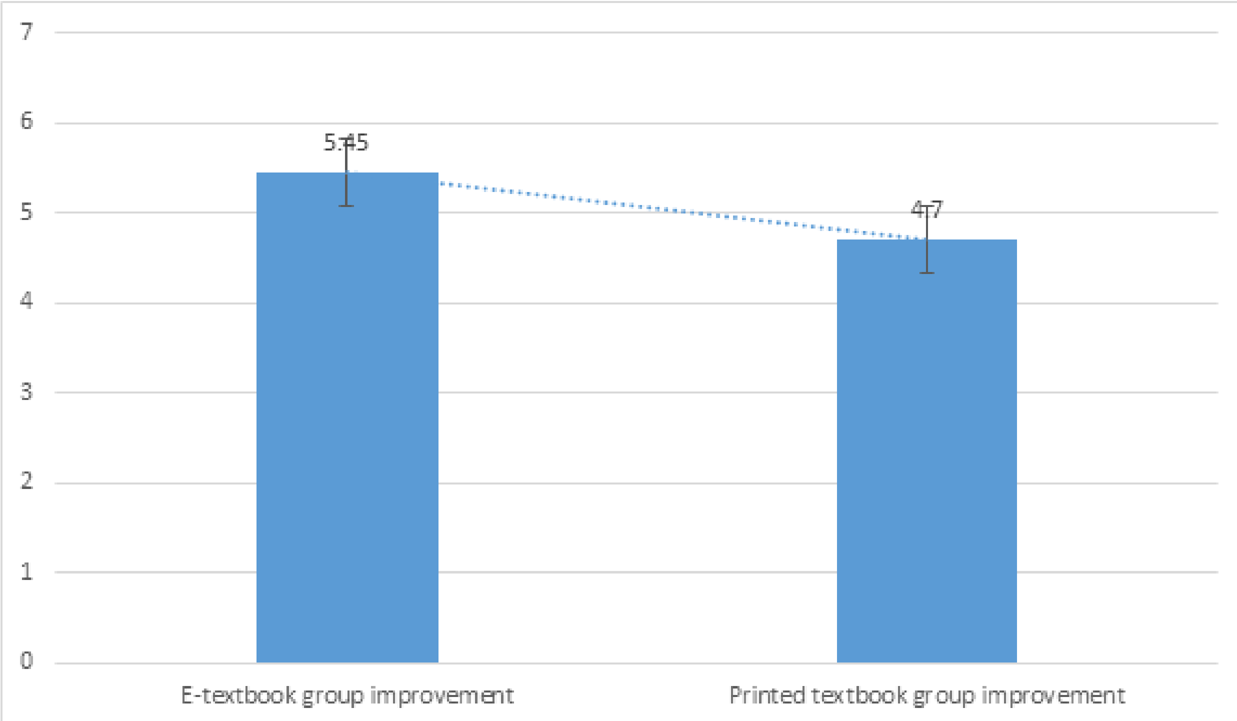

Figure 5.15: Hypothesis 15 Two-sample t-test Assuming Unequal Variances

	Mean	Standard deviation
E-textbook Group improvement	1.60	3.85
Printed Textbook Group improvement	6.40	3.21

Table 5.41: Hypothesis 16 Two-sample t-test Assuming Unequal Variances

An independent t-test was done on the mean score of the improvement of graduate students in the e-textbook group and the mean score of the improvement of graduate students in the printed textbook group. The test gave a t-statistical of -2.14 and p-value of 0.069. With p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that there was a statistically significant difference between the mean improvement of graduate students in the e-textbook group and the mean improvement of graduate students in the printed textbook group with 95% confidence. See Table 5.41 and Figure 5.16 shows individual value plot.

These results are summarized and discussed at the end of this chapter.

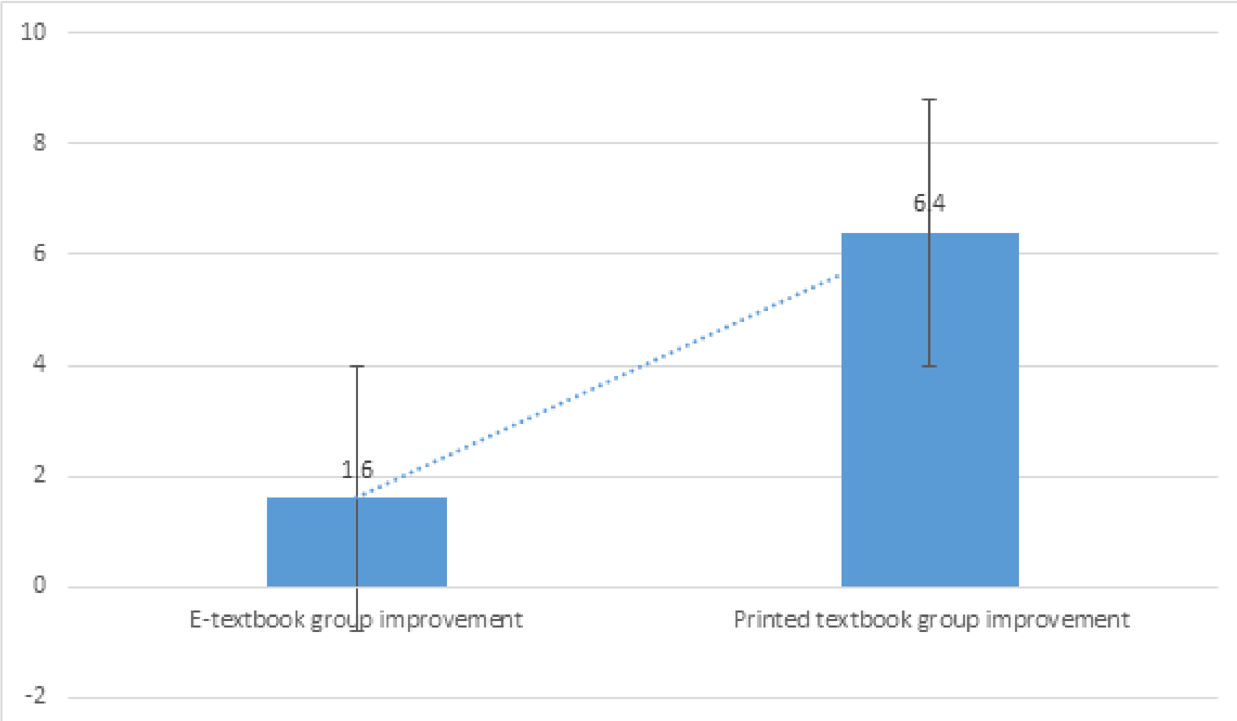

Figure 5.16: Hypothesis 16 Two-sample t-test Assuming Unequal Variances

5.2.2 User Interface Evaluation Survey

Q3. Do students like interacting with the interface of an e-textbook and does it increase a student's engagement with the course material?

The students' answers to the questions of the user interface evaluation survey are helpful in answering the third research question stated above. It should be noted that these are the answers of all students who used the e-textbook, undergraduate students and graduate students (n = 16). We report on their answers below and discuss them later on.

Reaction to the interface:

1. Overall reaction to the interface (terrible - wonderful): see Figure 5.17

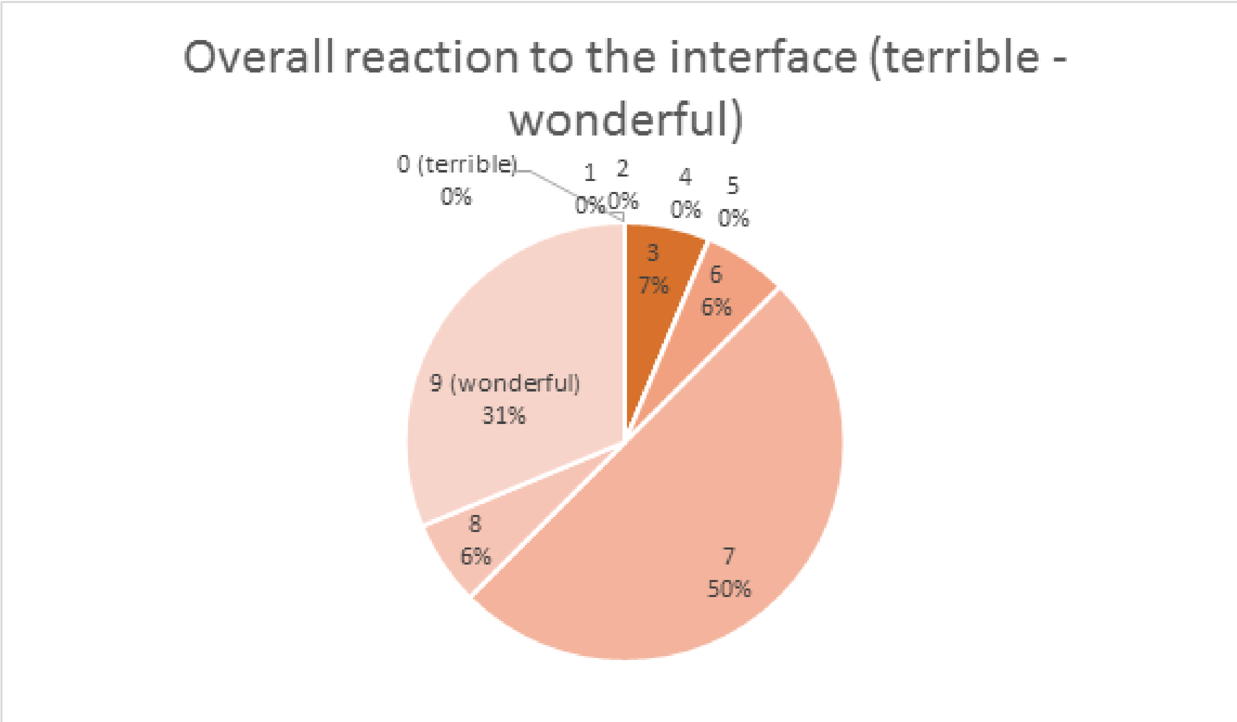

Figure 5.17: Overall reaction to the interface (terrible - wonderful)

2. Overall reaction to the interface (difficult - easy): see Figure 5.18

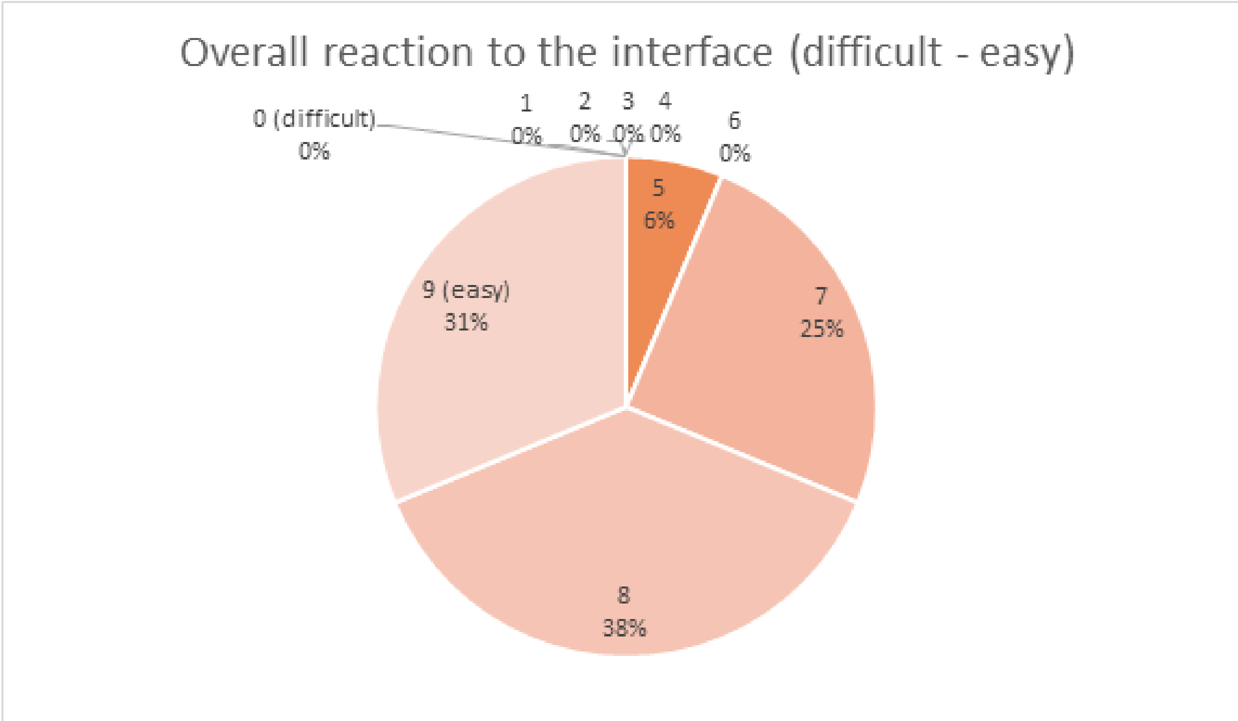

Figure 5.18: Overall reaction to the interface (difficult - easy)

3. Overall reaction to the interface (frustrating - satisfying): see Figure 5.19

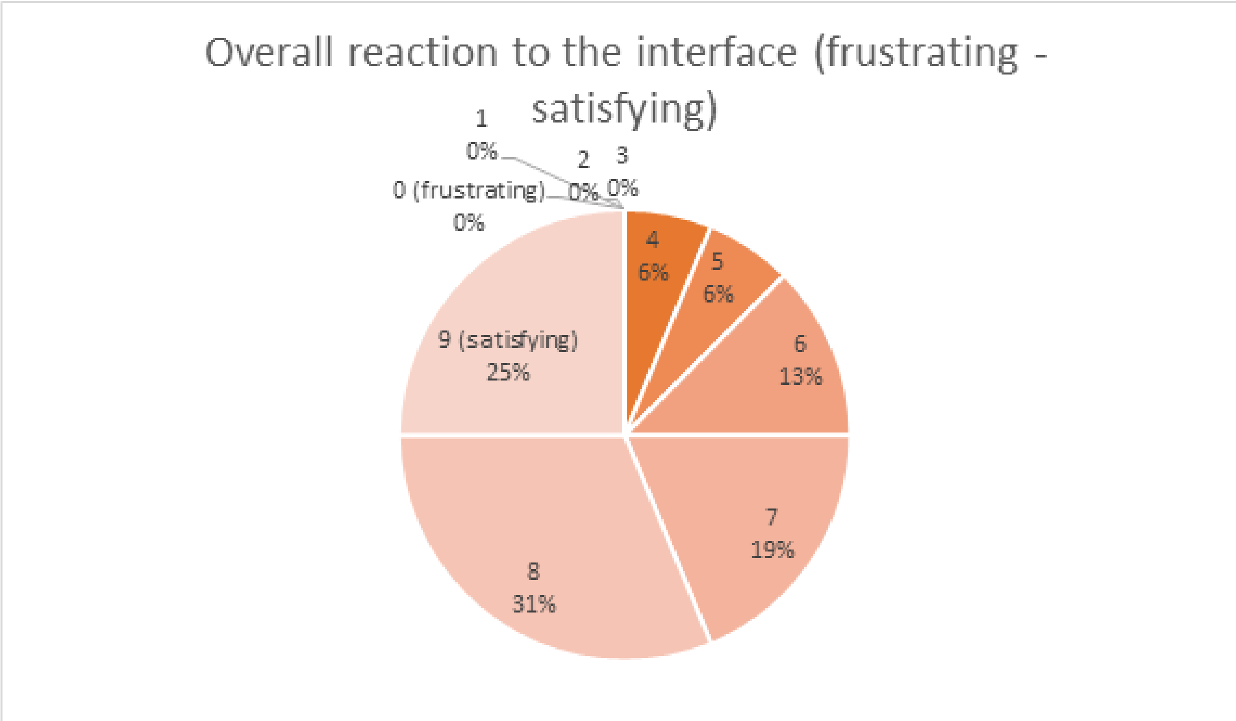

Figure 5.19: Overall reaction to the interface (frustrating - satisfying)

4. Overall reaction to the interface (dull - stimulating): see Figure 5.20

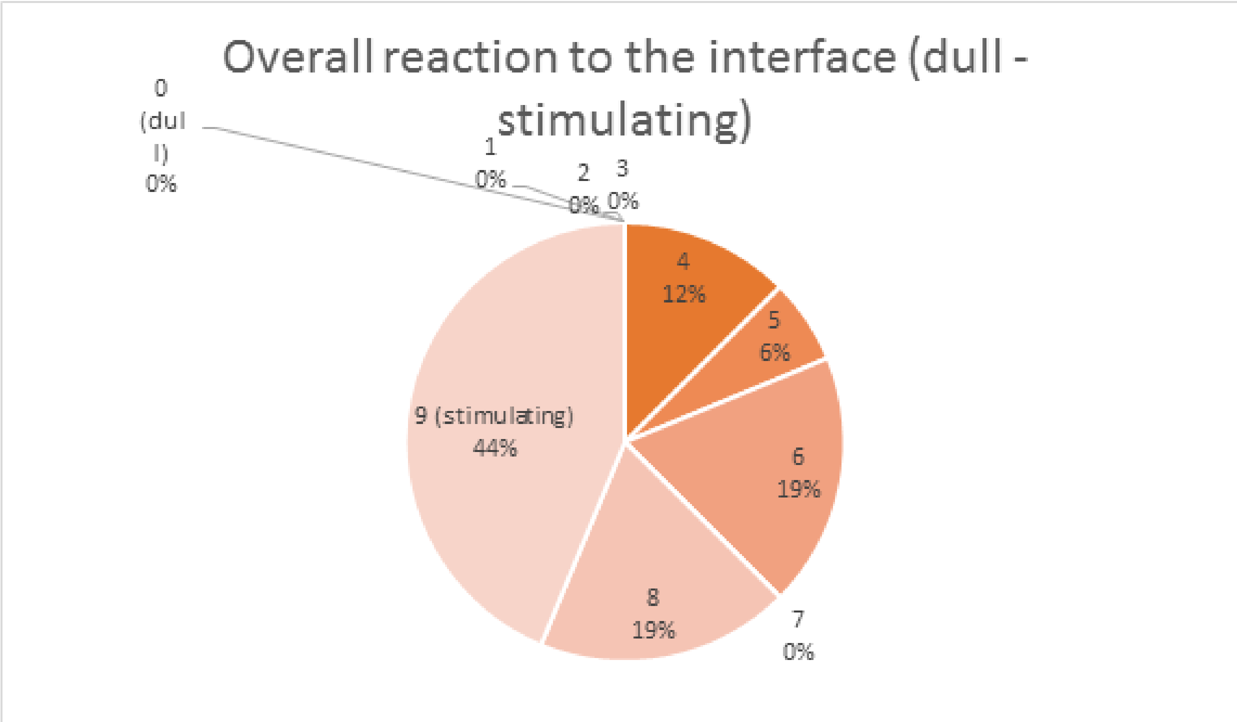

Figure 5.20: Overall reaction to the interface (dull - stimulating)

5. Overall reaction to the interface (rigid - flexible): see Figure 5.21

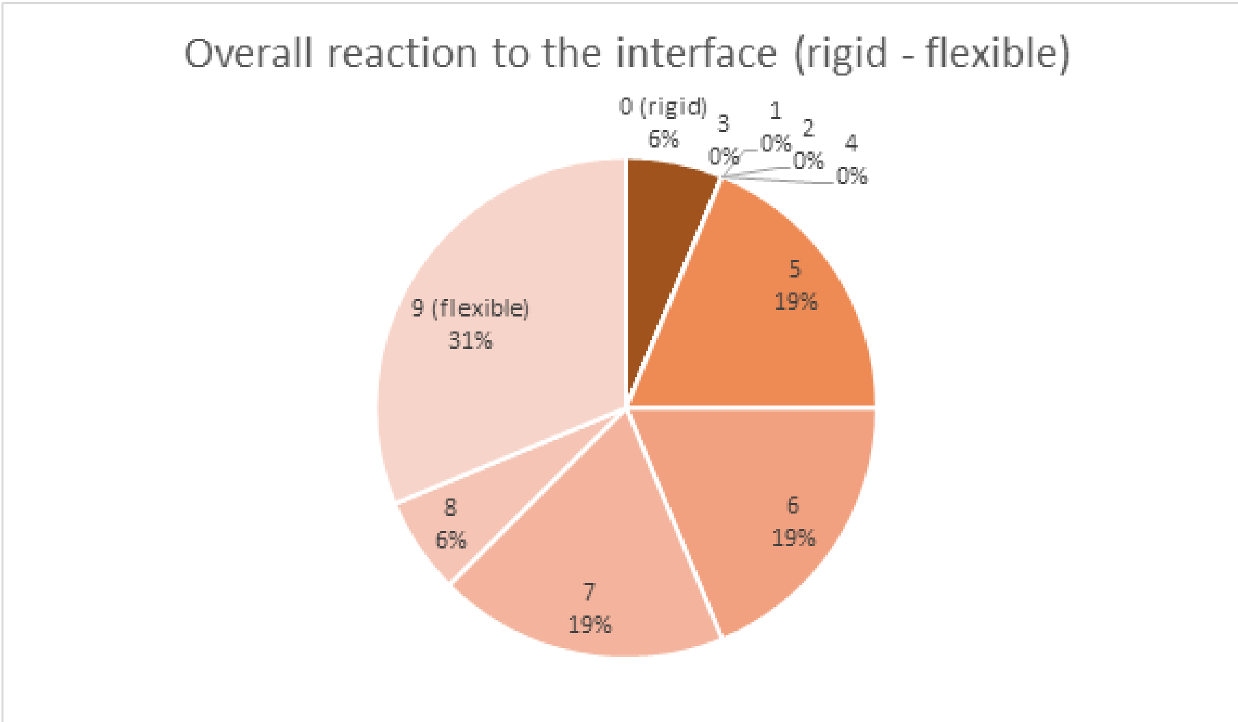

Figure 5.21: Overall reaction to the interface (rigid - flexible)

Screen:

1. Screen: Overall layout: see Figure 5.22

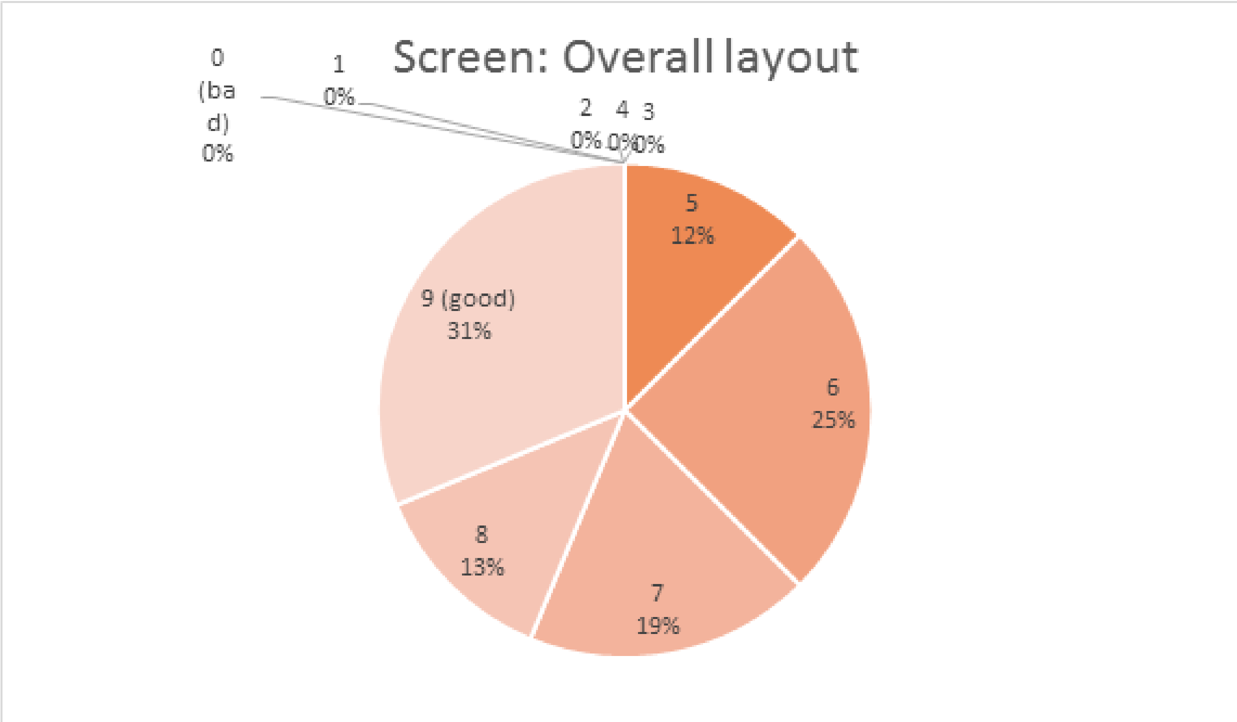

Figure 5.22: Screen: Overall layout

2. Screen: The color scheme: see Figure 5.23

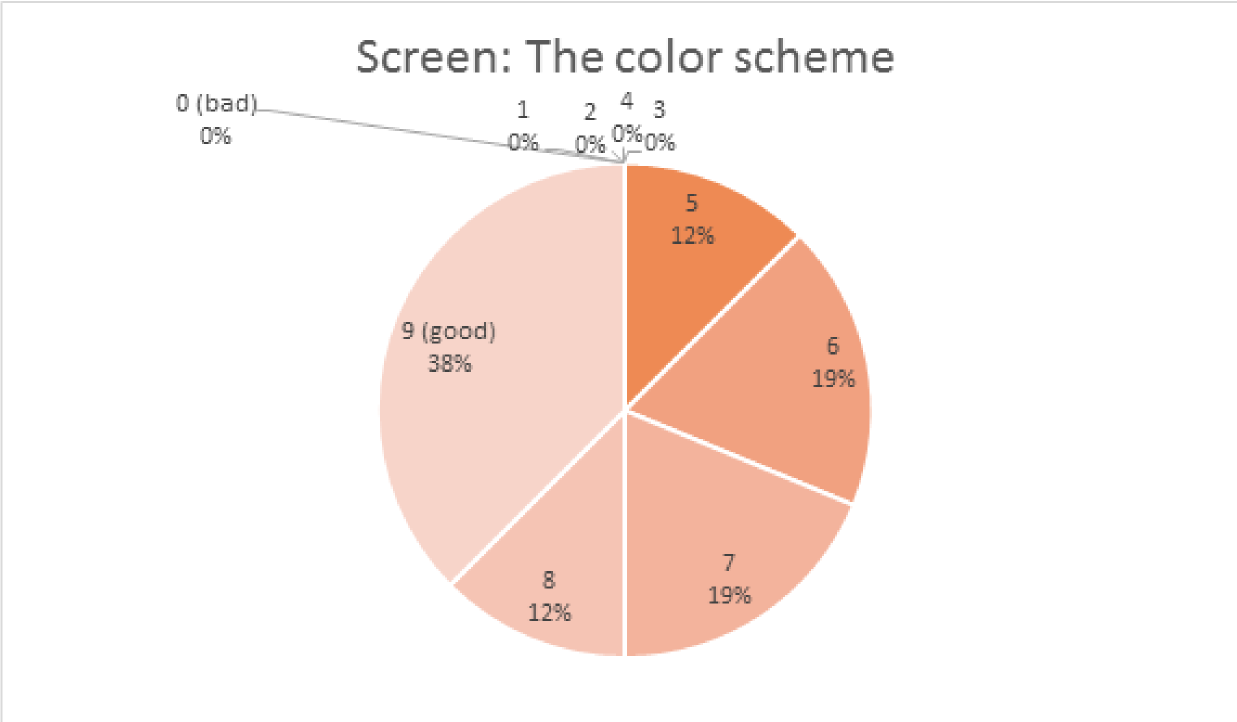

Figure 5.23: Screen: The color scheme

3. Screen: Font style (size, color...): see Figure 5.24

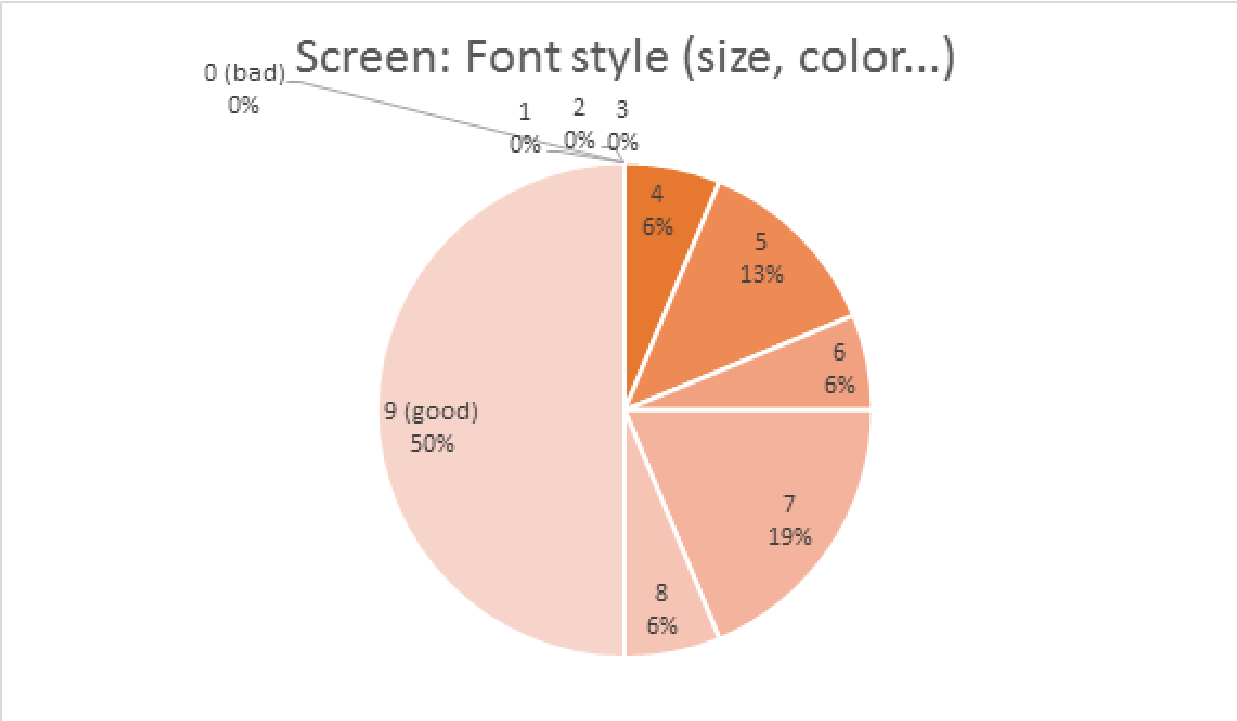

Figure 5.24: Screen: Font style (size, color...)

4. Screen: Separation/ layout of the information with concept maps on the left and text on the right: see Figure 5.25

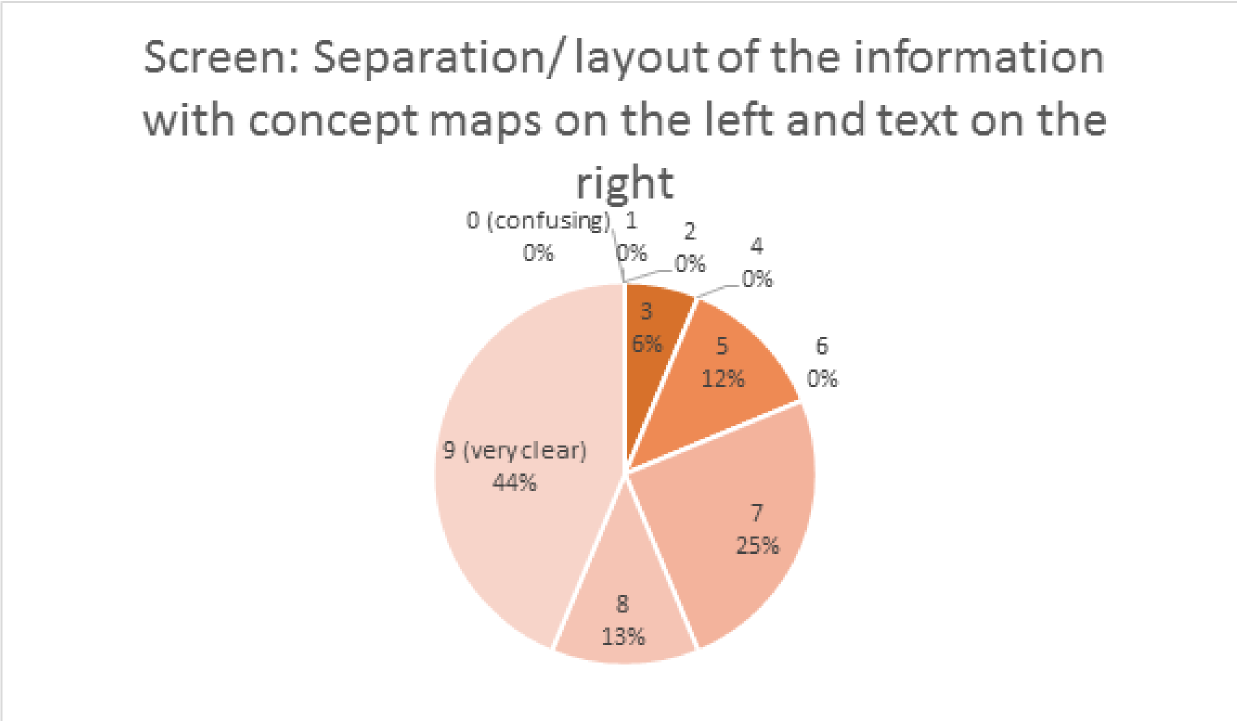

Figure 5.25: Screen: Separation/ layout of the information with concept maps on the left and text on the right

5. Screen: Sequence of screens: see Figure 5.26

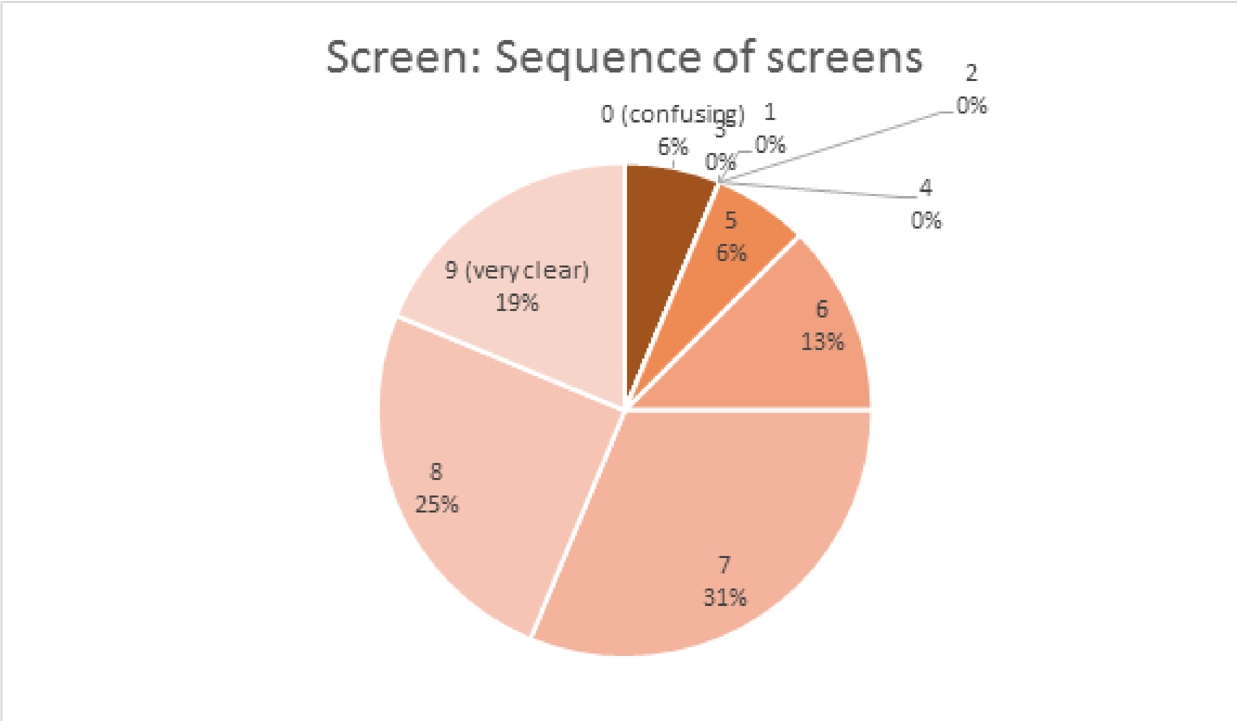

Figure 5.26: Screen: Sequence of screens

6. Screen: Use of terms throughout the system: see Figure 5.27

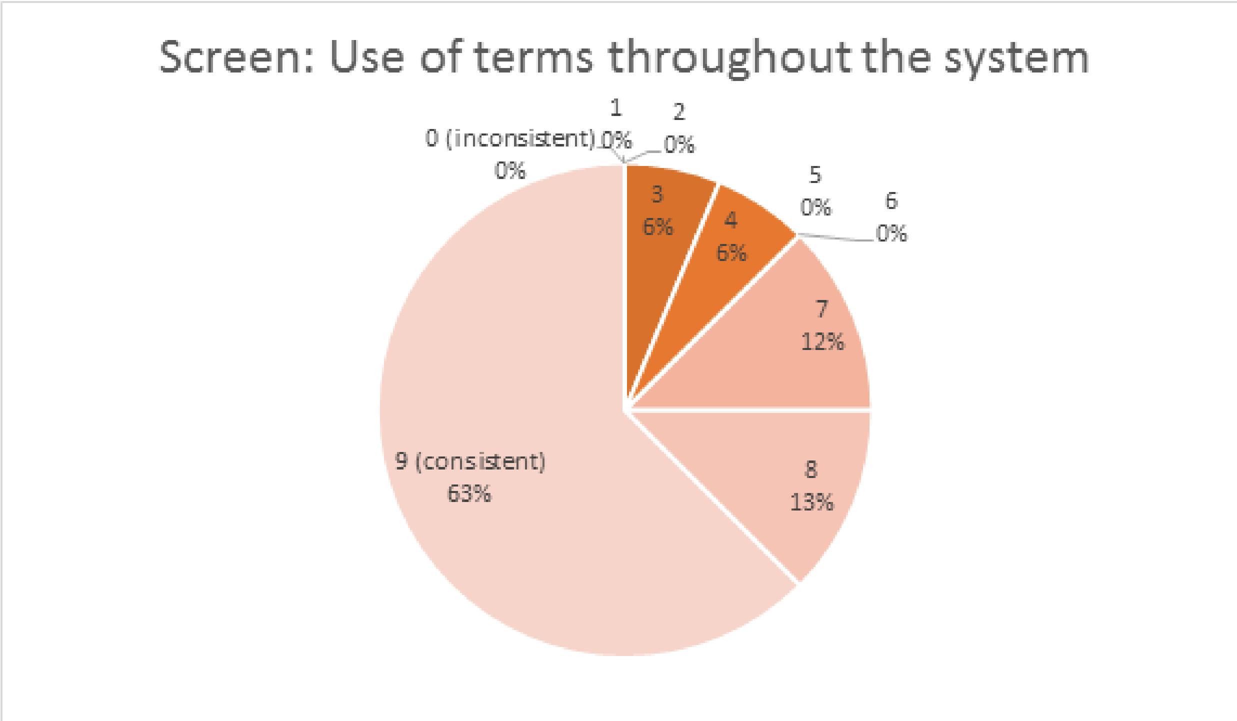

Figure 5.27: Screen: Use of terms throughout the system

Learning:

1. Learning to use the system: see Figure 5.28

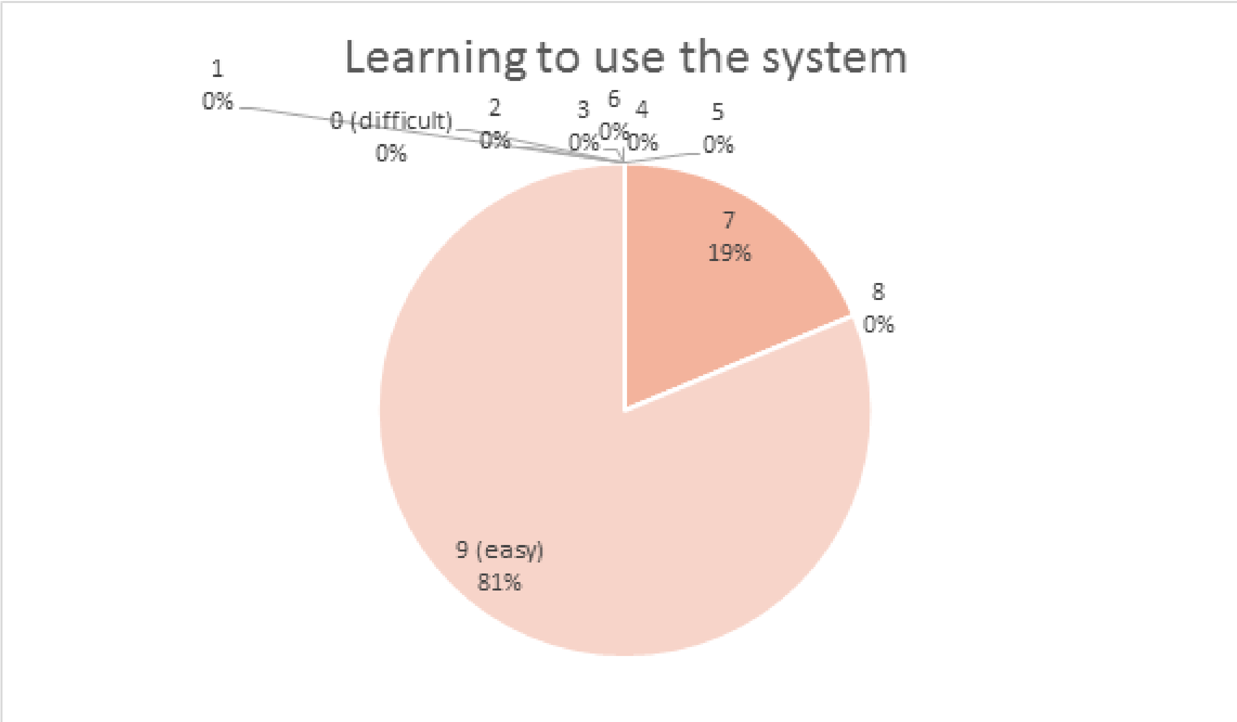

Figure 5.28: Learning to use the system

2. Exploring features by trial and error: see Figure 5.29

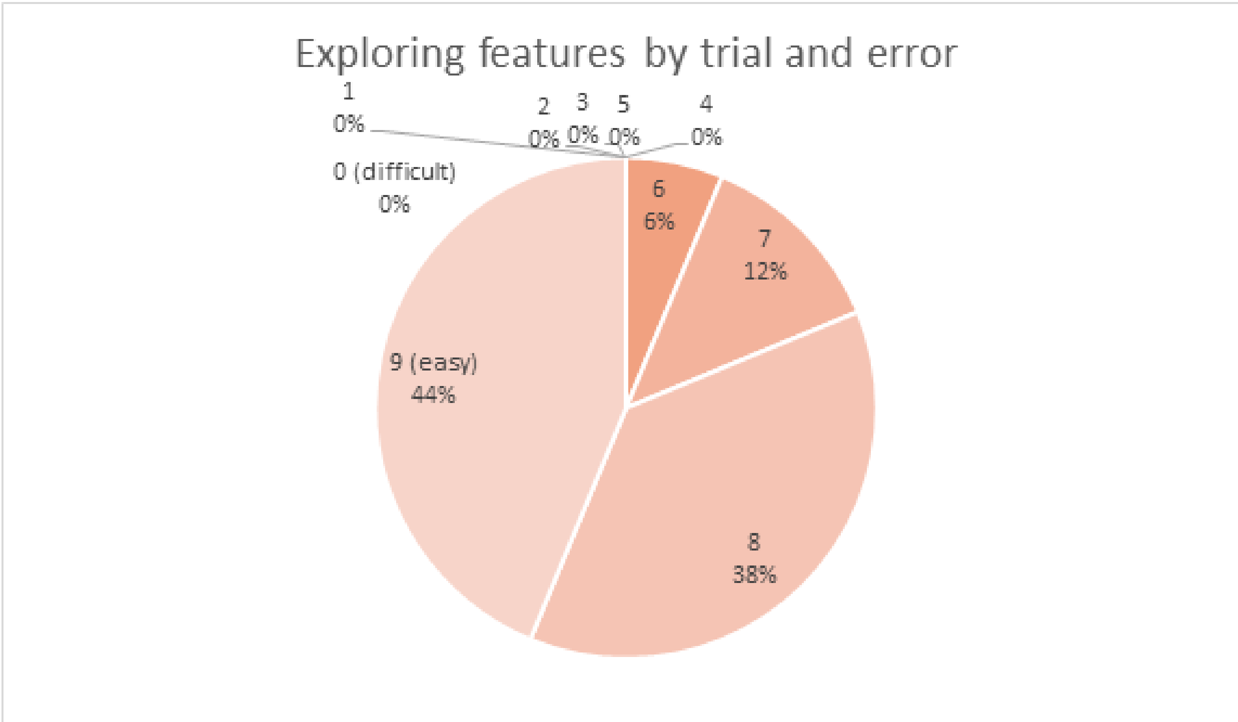

Figure 5.29: Exploring features by trial and error

3. Navigation is straightforward: see Figure 5.30

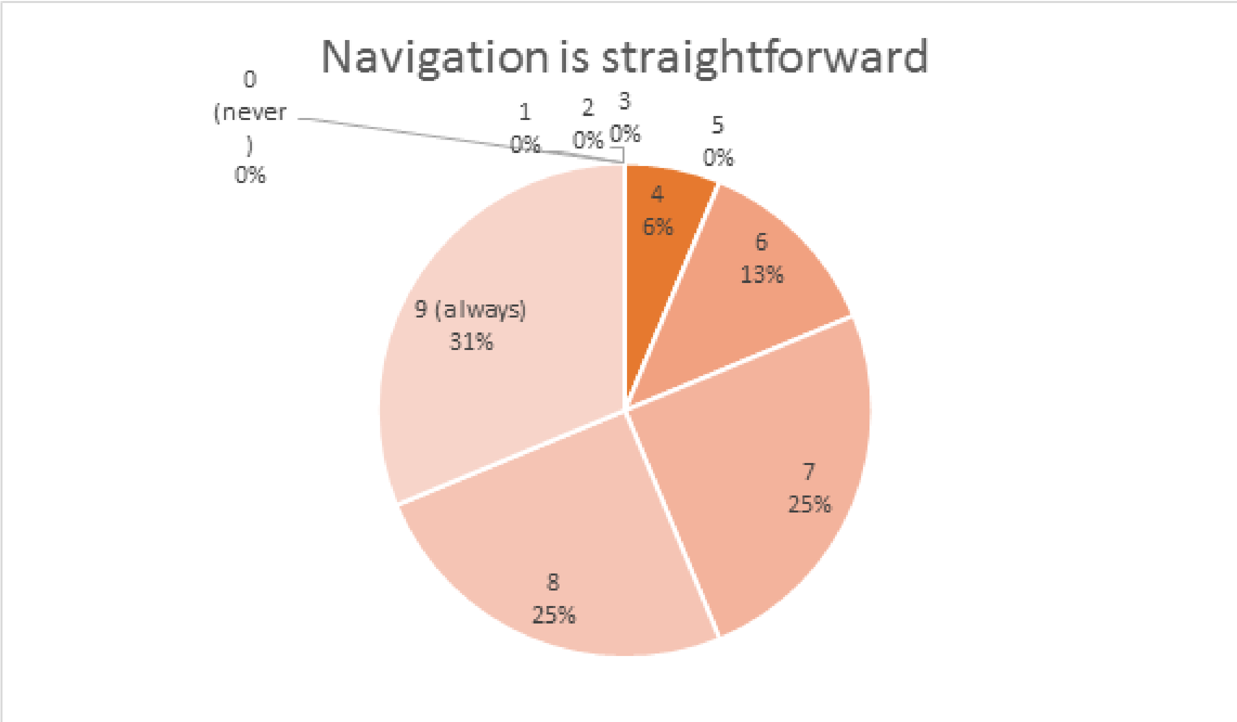

Figure 5.30: Navigation is straightforward

4. Help menu item: see Figure 5.31

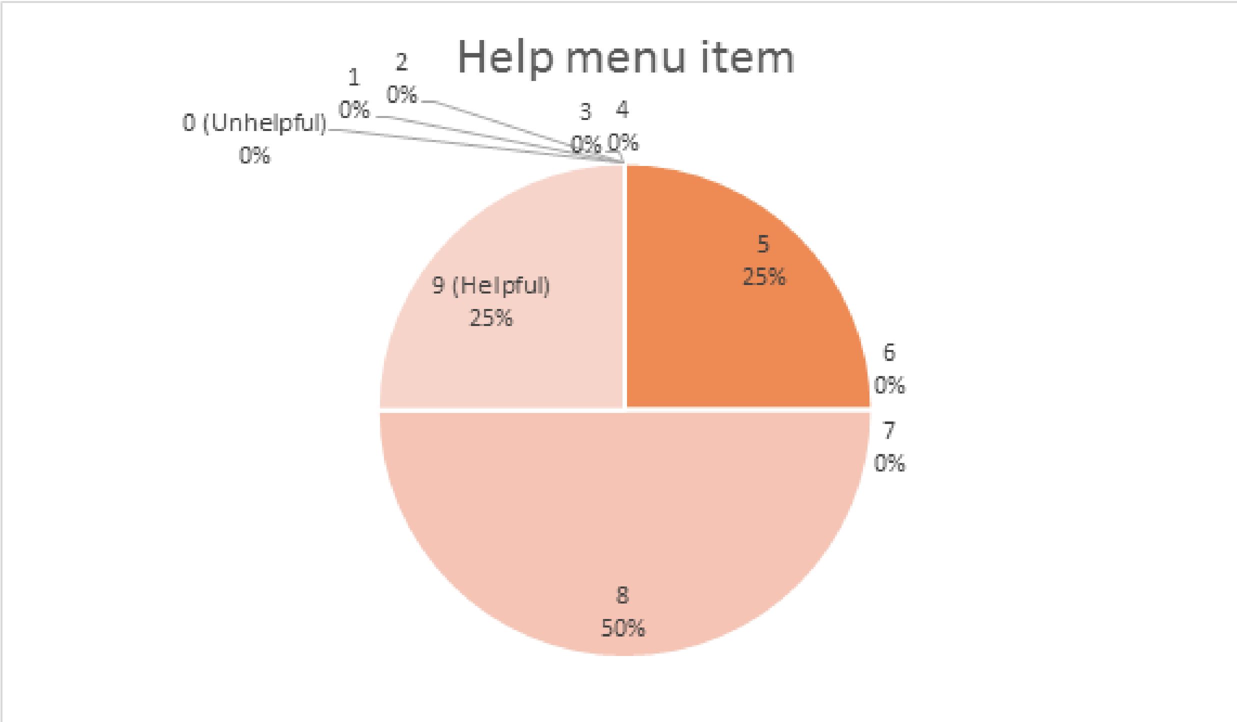

Figure 5.31: Help menu item

Content:

1. The concept map is helpful in understanding the relationships between graph concepts: see Figure 5.32

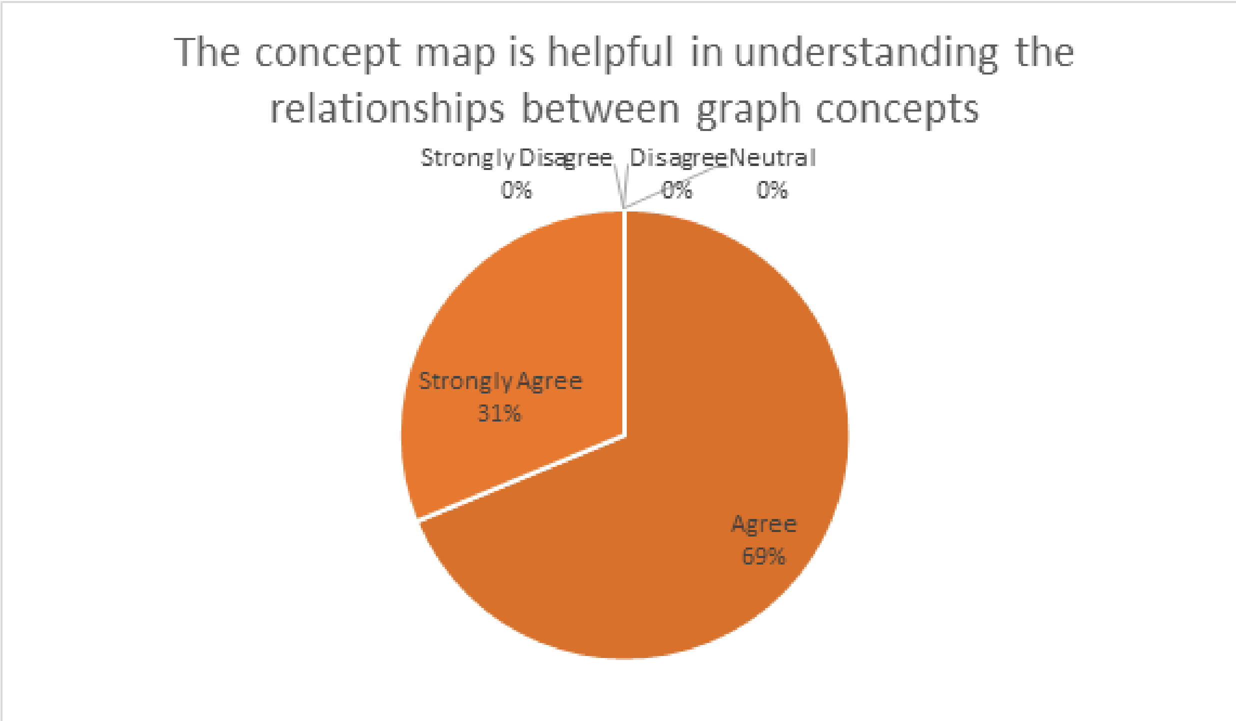

Figure 5.32: The concept map is helpful in understanding the relationships between graph concepts

2. The concept map is helpful in navigating the system: see Figure 5.33

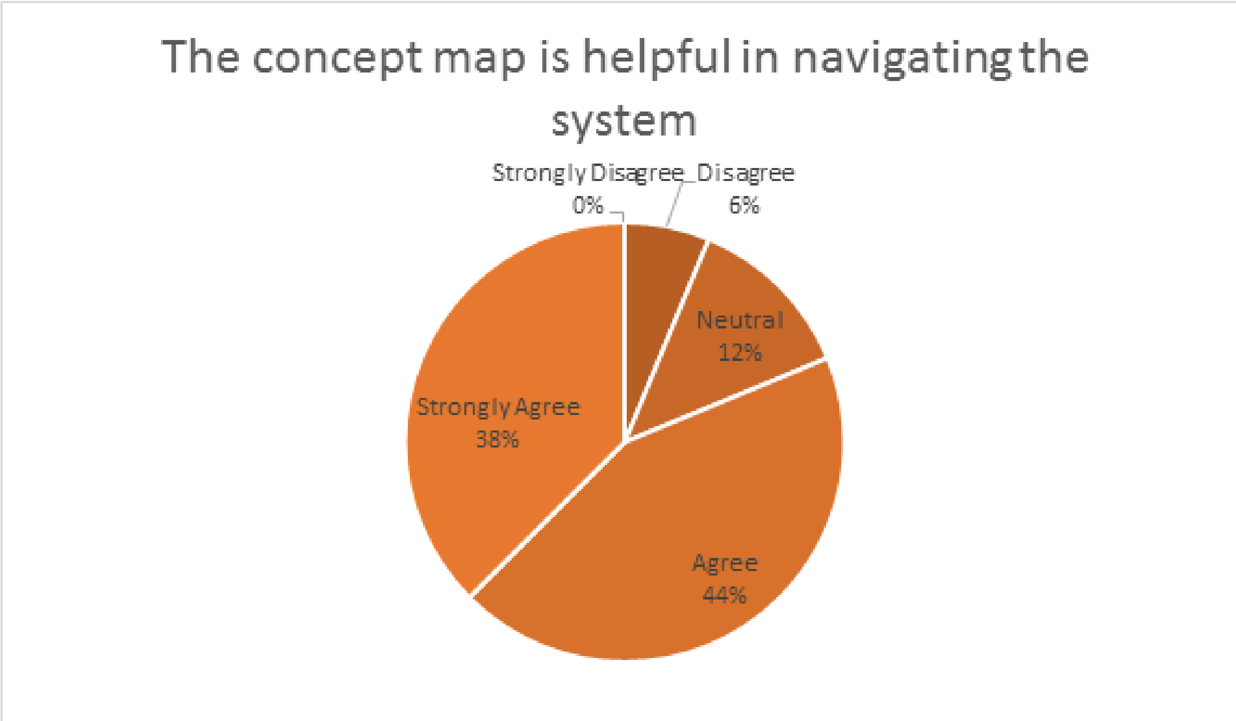

Figure 5.33: The concept map is helpful in navigating the system

3. The information presented is useful: see Figure 5.34

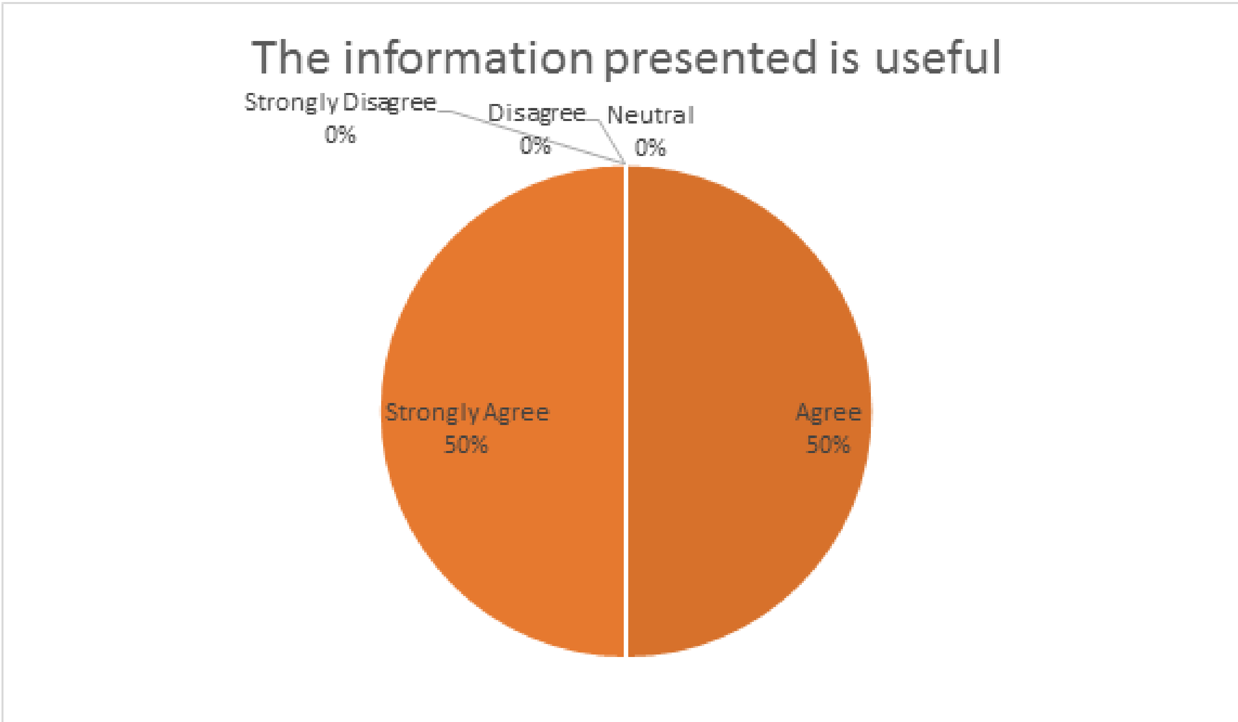

Figure 5.34: The information presented is useful

4. The information presented is interesting: see Figure 5.35

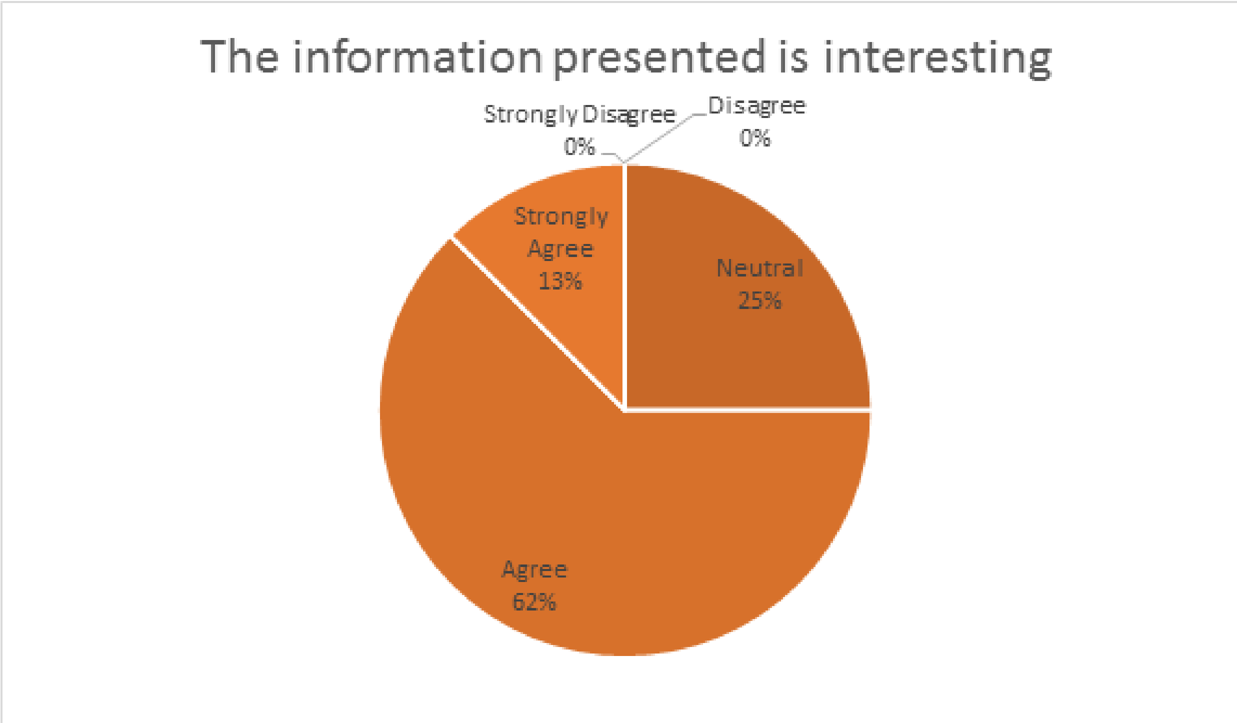

Figure 5.35: The information presented is interesting

5. The definitions of concepts are clear: see Figure 5.36

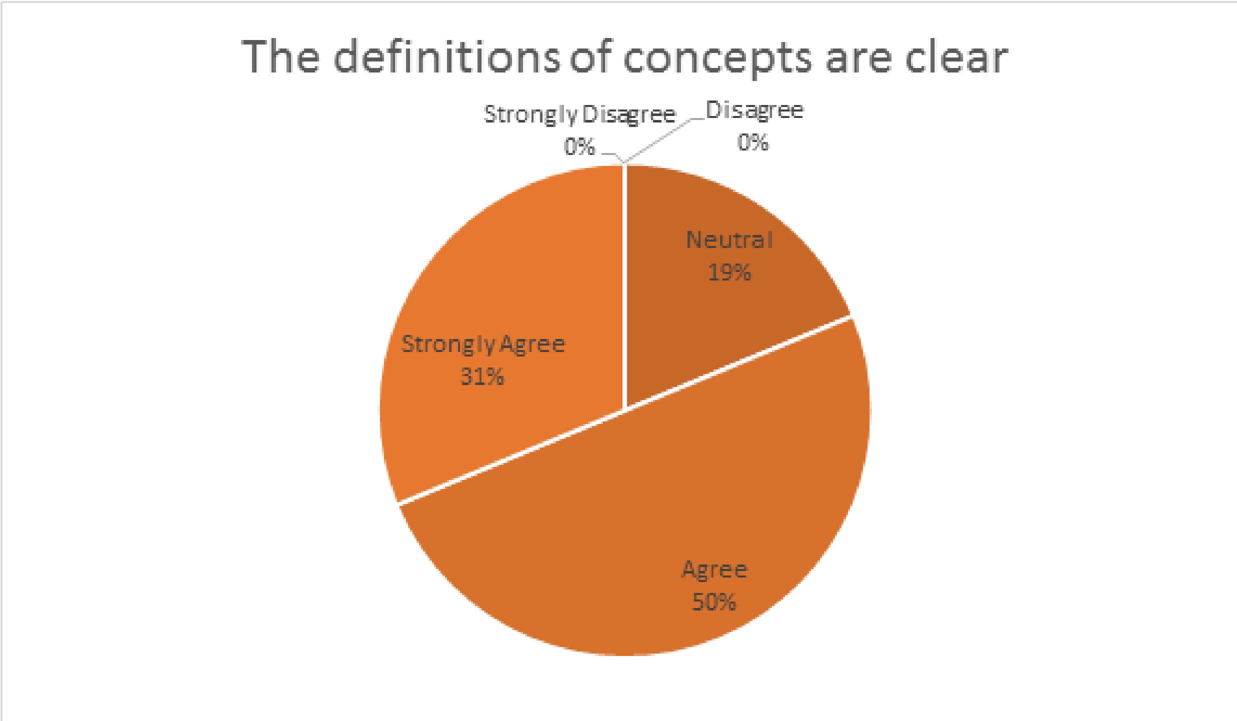

Figure 5.36: The definitions of concepts are clear

6. The examples helped me understand concepts better: see Figure 5.37

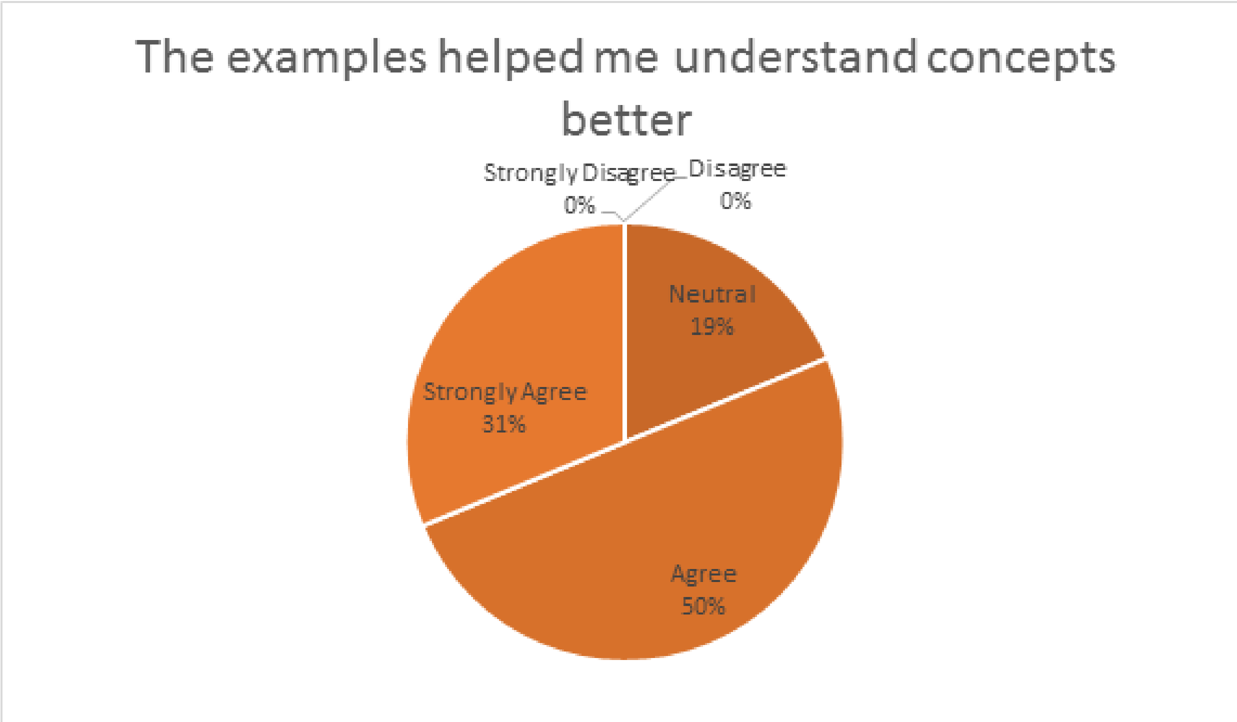

Figure 5.37: The examples helped me understand concepts better

7. The animations helped me understand concepts better: see Figure 5.38

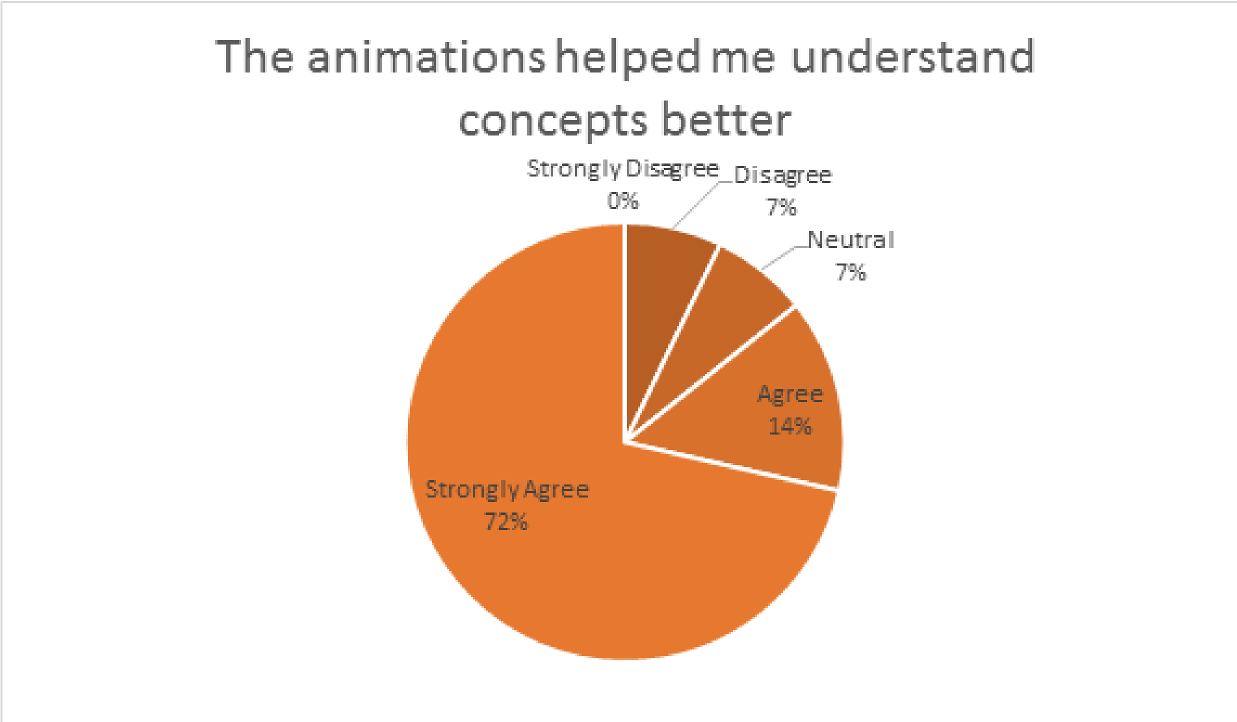

Figure 5.38: The animations helped me understand concepts better

8. The algorithms helped me understand concepts better: see Figure 5.39

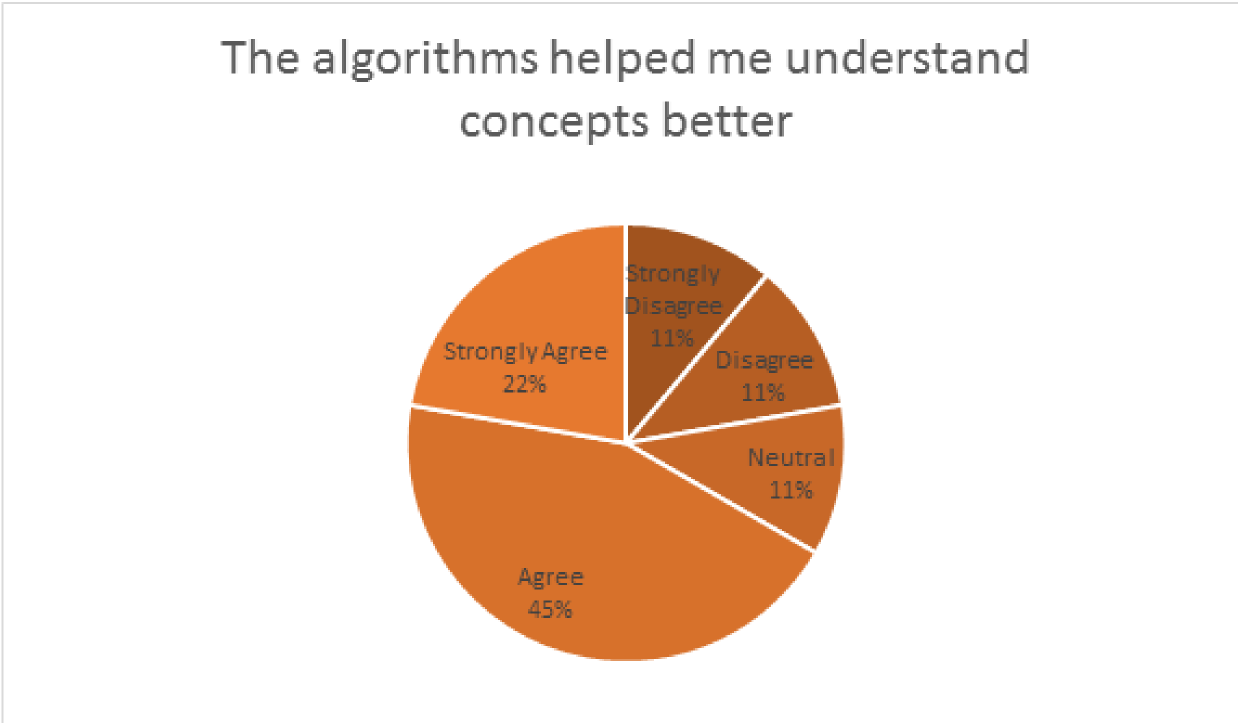

Figure 5.39: The algorithms helped me understand concepts better

9. I gained new knowledge about graph data structure and algorithms from the system: see Figure 5.40

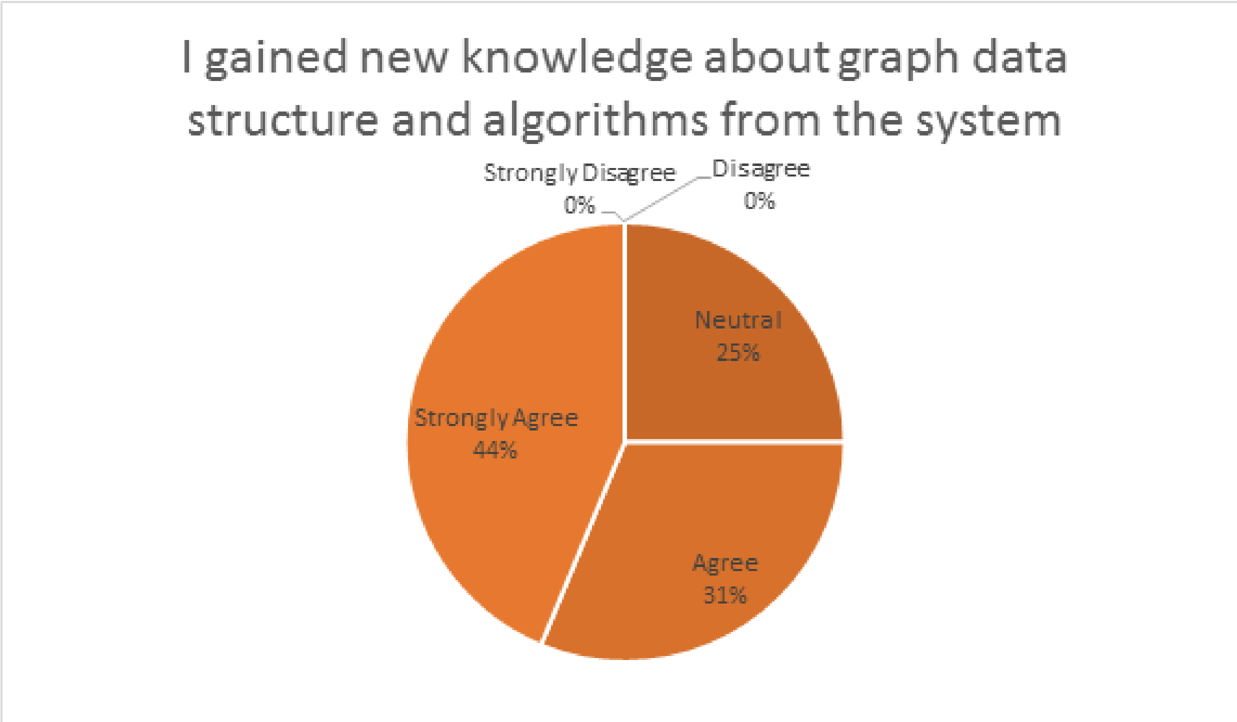

Figure 5.40: I gained new knowledge about graph data structure and algorithms from the system

10. I think the system helped me understand the concepts better than a textbook: see Figure 5.41

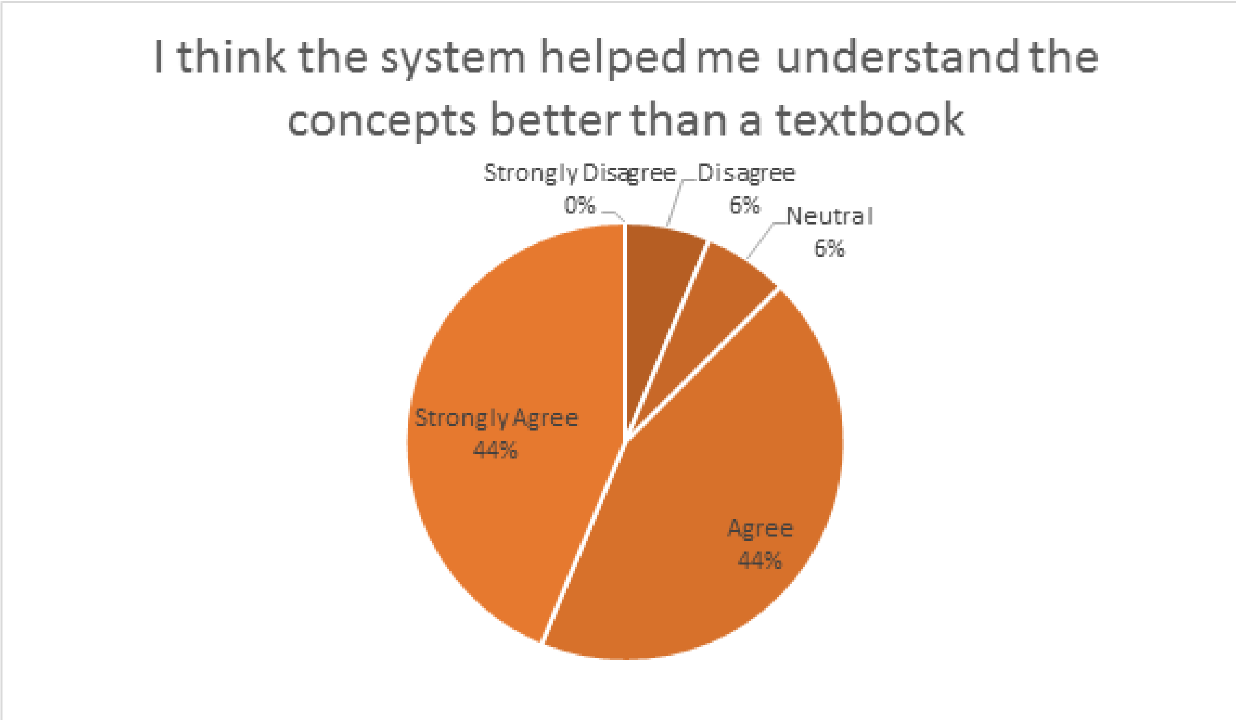

Figure 5.41: I think the system helped me understand the concepts better than a textbook

These results are summarized and discussed at the end of this chapter.

5.2.3 Log Files

To track the user interactions with the e-textbook, we used Opentracker[1] and Google Analytics[2]. While Opentracker provided a separate log file for each user listing the visited pages and the viewed concepts, Google Analytics provided an analysis for all user behaviors with the e-textbook giving a generalized look of the visited pages and the time spent on the e-textbook.

The log files show that if pages were ordered from the most visited to the least visited, then the result would be the following list:

1. Home Page

[1]http://www.opentracker.net/
[2]http://www.google.com/analytics/

2. Graph Types
3. Graph Components
4. Graph Operations
5. Acyclic Graph
6. Graph Representation
7. Edge
8. Tree
9. About
10. Contact
11. Help

The list shows that the Help page is the least visited page, which means that not many student needed to view it, and this shows that the interface was easy to use and did not require help or explanation.

The log files also show that the average time spent on a page is 49 seconds. Graph Representation is the page that students spent most time on which was on average 1 minute and 46 seconds.

In addition, the log files provide the behavior flow of users. Behavior flow shows the path the users go through to navigate from one page to another. One such path starts with the Home Page, then Graph Components, the visiting Edge page, and then going back to Graph Components page. Another path starts with Home Page, then Graph Types, then Acyclic Graph, and the last page is Tree.

It should be noted that Opentracker logs only show the last 40 events of a users visit, an issue that we were not able to solve even after contacting the company. See appendix F for Google Analytics complete reports.

5.3 Discussion

Results from the statistical analysis showed that undergraduate students (both who had previous knowledge and who had limited previous knowledge) performed better in the posttest after using the e-textbook. These results meet our expectation and answer our first research question about whether an e-textbook improves students' learning. However, these results did not apply to graduate students. The statistical analysis performed on graduate students' scores did not show a significance difference between pretest and posttest scores that we could use to generalize the results and claim that e-textbook would improve graduate students' performance. One possible reason behind this result is the small number of graduate students who volunteered to participate. We believe that if the sample was greater, then we might have seen a different result. A second reason is the fact that this e-textbook prototype had content at an undergraduate level. Most graduate students had good knowledge of the content and could answer most pretest questions easily prior to using the e-textbook (See figure 5.4 on page 54). This is especially evident from the high pretest score (mean 23.6) of the e-textbook group indicating significant prior knowledge. We recommend conducting further research with graduate students and e-textbooks that have content at the graduate level.

As for our second research question, results showed that an e-textbook does not necessarily improve learning better than a traditional printed textbook. Nevertheless, as can be seen from table 5.42, among undergraduate students, the e-textbook groups performed as well or better than the text groups, even though these differences were not statistically significant. The graduate students text group performed better than the e-textbook group, but again it should be noted that the graduate students text group had a lower level of prior knowledge (pretest mean 16.4) compared to the graduate students e-textbook group (pretest mean 23.6) and both received similar posttest scores (posttest means: e-textbook: 25.2 and text: 22.8). We believe the reasons for these results are similar to the reason stated before about graduate students performance. Many of the undergraduate students who participated

	Text Group Improvement Scores	E-Text Group Improvement Scores
COMP 3270	5	4.875
Other UG	4	7
All Undergraduate	4.7	5.45
All Graduate	6.4	1.6

Table 5.42: Improvement scores of all groups

on the study had some previous knowledge about graph data structure, which meant that they could answer many of the pretest questions easily. In addition, the sample is relatively small. Performing the study on a larger sample may yield different results. It is also possible that an e-textbook may be beneficial to younger and less knowledgeable undergraduate students, such as freshmen. We recommend conducting further research to answer this question with a larger sample size, undergraduates at various levels, an e-textbook that is richer in interactive contents that really differentiates it from the traditional printed textbook, and for a longer period. Instead of students having 30 minutes to study from the e-textbook, it would be more effective if the study would be conducted on a whole term material where the students would use the e-textbook for the entire duration of a course.

The third research question is answered by going through students' reaction to the e-textbook. Results from usability testing showed that the rating of the e-textbooks interface and features fell within the range of 6 to 9 (9 is the high end of the scale). All four participants in the usability testing thought that layout of the e-textbook (the separation of the concept map and the text) was very clear. Moreover, all of the usability testing participants said that the e-textbook helped them understand the material better than a printed textbook.

The results from the actual testing also showed a positive attitude toward the e-textbook with 88% of the students who used it saying that the e-textbook helped them understand the material better than a traditional textbook. 66% of students said that animations helped understand the concepts better, and 75% said algorithms helped them understand concepts better. Most of the students who used the e-textbook liked navigating the system with the concept map (38% chose Strongly Agree, 44% chose Agree). Furthermore, all of the students who used the e-textbook agreed to the fact that the concept map helped them to understand the relationships between the different concepts (69% chose Agree, 31% chose Strongly Agree).

The students did not only have a positive reaction to the e-textbook, they also gave insightful thoughts on how to further develop it and make it more interactive and engaging. Some of the comments that students wrote include adding a History feature that keeps track of what concepts the student had already viewed, a full concept map that shows all concepts on one screen, and a guide that suggests what concepts to visit next in order to completely understand the material. Interestingly, this suggestion of a navigation guide corresponds with the finding of Puntambekar and Stylianou[9] that students who were provided with navigation support in CoMPASS performed better.

Chapter 6

Conclusion and Future Work

The work described in this thesis has been concerned with the development of an e-textbook on the subject of graph data structures and algorithms. Our e-textbook works on tablet devices as well as on PCs and laptops because it uses JavaScript for its interactive elements and does not require additional browser plug-ins to be installed, making it platform independent.

Our experiments tackled three research questions: does an e-textbook improve a student's learning as measured by his/her performance in a test? Does an e-textbook improve a student's learning and performance better than a printed textbook? Do students like interacting with the interface of an e-textbook and does it increase a student's engagement with the course material? Tests using the developed e-textbook showed an improvement in students' performance. While the tests were not sufficient to conclude whether an e-textbook improves performance better than a printed textbook, it showed a clear positive attitude toward the e-textbook and its interactive elements.

The positive feedback received from students gives motivation to improve this prototype and develop it more. This improvement can begin with enriching the e-textbook's content and adding more interactive elements. Specifically, interactive exercises that asses students understanding of the material and provide immediate feedback can be included in the e-textbook. In addition, implementing a history feature that keeps track of viewed concepts on each session and storing this history to be viewed on a later session is another improvement. Furthermore, building a backend to the e-textbook that allows instructors to add, delete, and edit concepts, edit content, author new exercises or edit existing ones or delete them is a necessary next step. Also, providing the ability to track students' progress with the material, grade assignments and tests would be advantageous. Moreover, the e-textbook can provide a platform of communication between instructors and students. Students can post questions about the materials or ask for further explanation on a concept on the e-textbook pages and instructors' answers can further extend the e-textbook, allowing instructors to adapt and extend the e-textbook over time to suit their classes.

The current prototype of the e-textbook can serve as a basis for further development in this field of research, and this study can serve as a start for studies on the use and effect of e-textbooks inside classrooms over the course of an entire semester. E-textbooks not only affect students performance, but also affect how students perceive new knowledge presented in front of them, how they interact with this knowledge in order for them to apply it, and challenge them to be active learners instead of being passive learners. These effects in turn change the way instructors teach a course and how they communicate with the students. All of this can lead to a better learning environment that benefits from the fast advances of technology.

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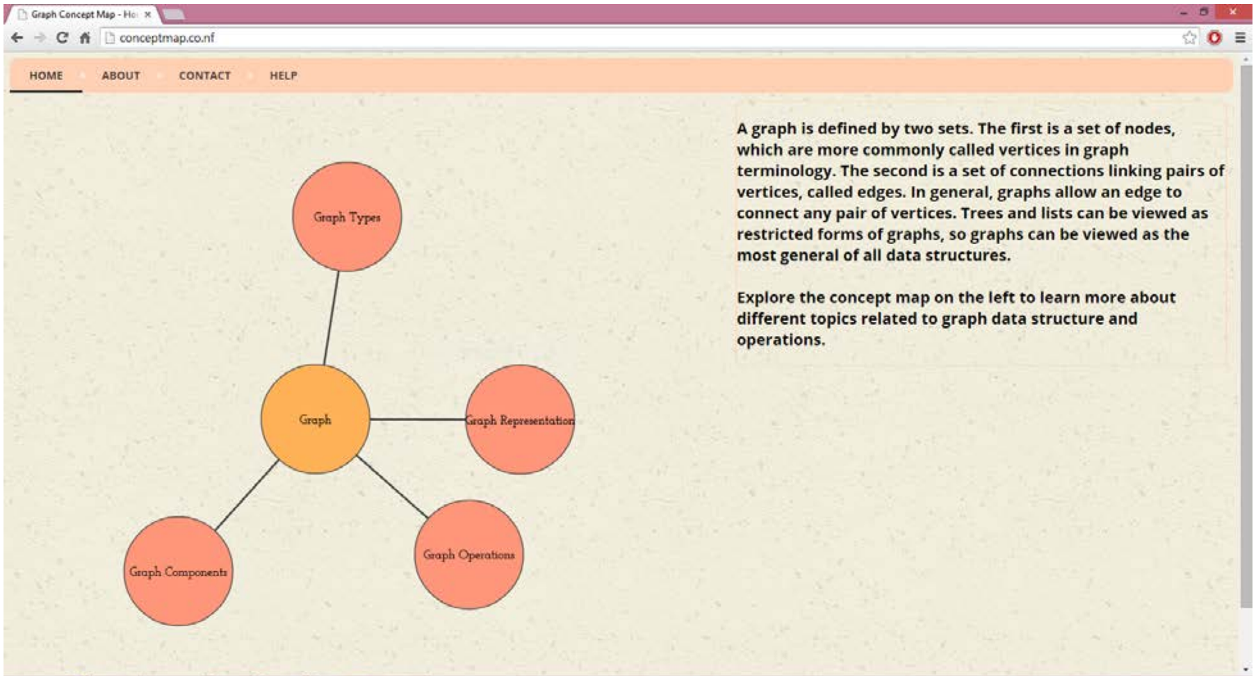
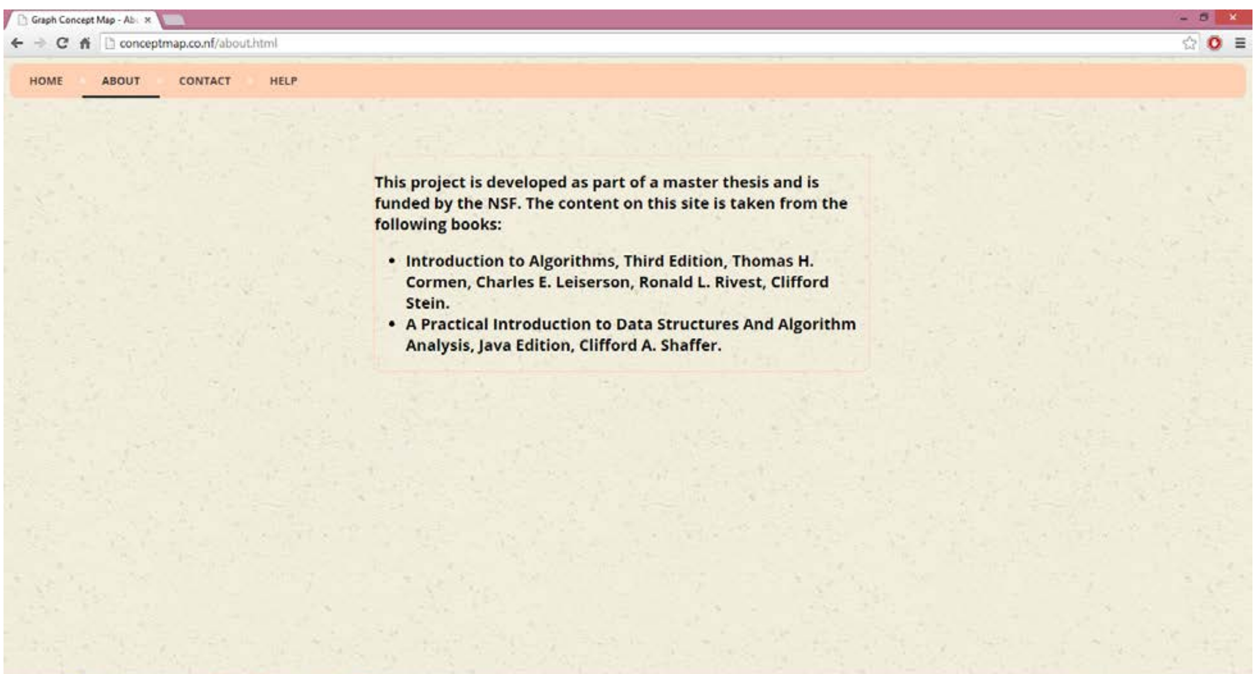
[11] Jenny Preece Yvonne Rogers, Helen Sharp. *Interaction Design: Beyond Human - Computer Interaction*. Wiley, 3rd edition, 2011.

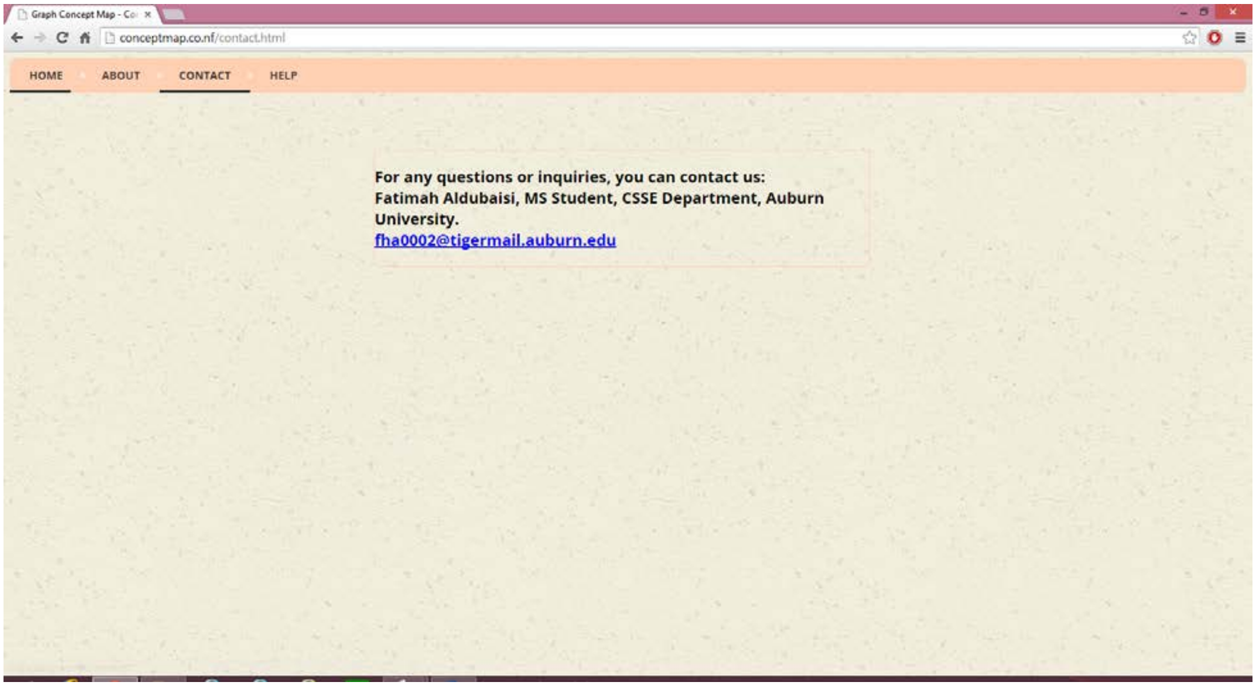
Appendices

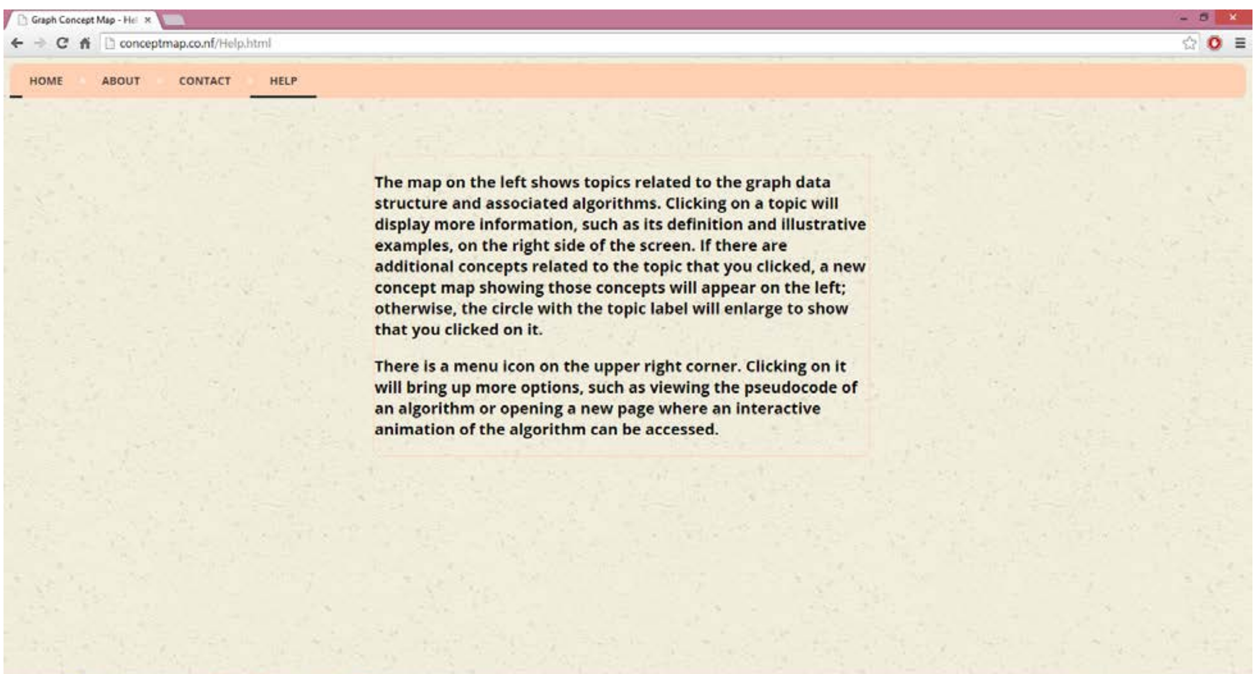
Appendix A

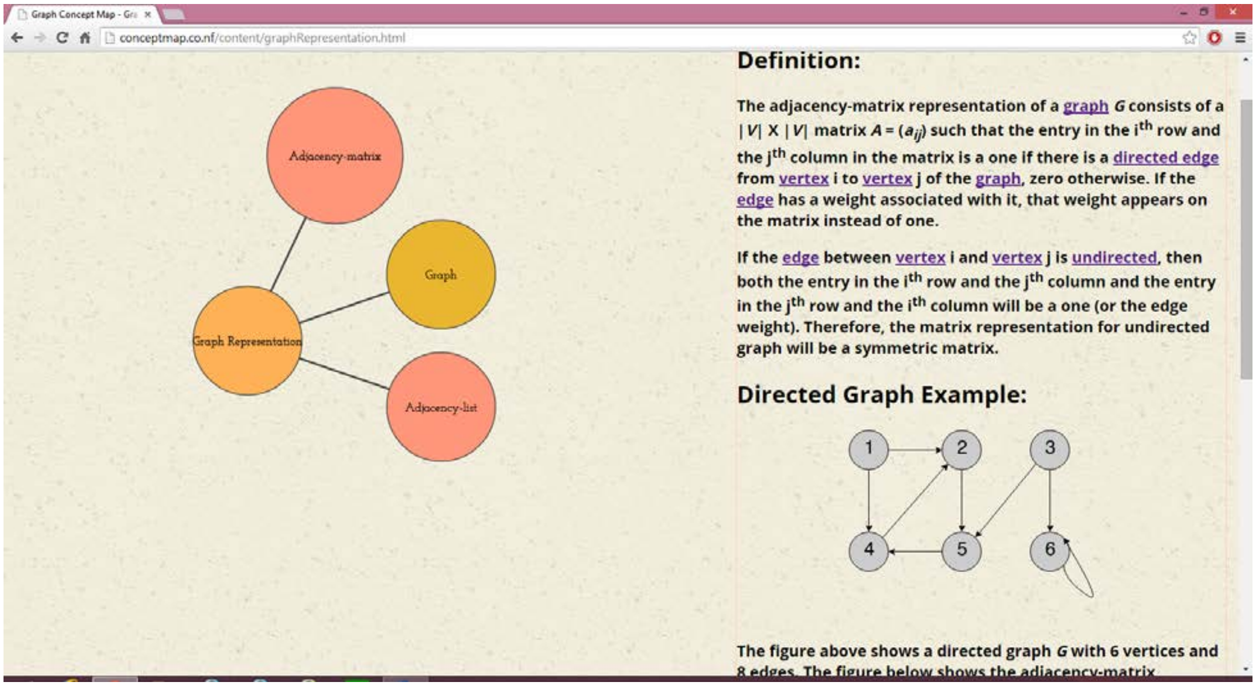
E-Textbook Screen Shots

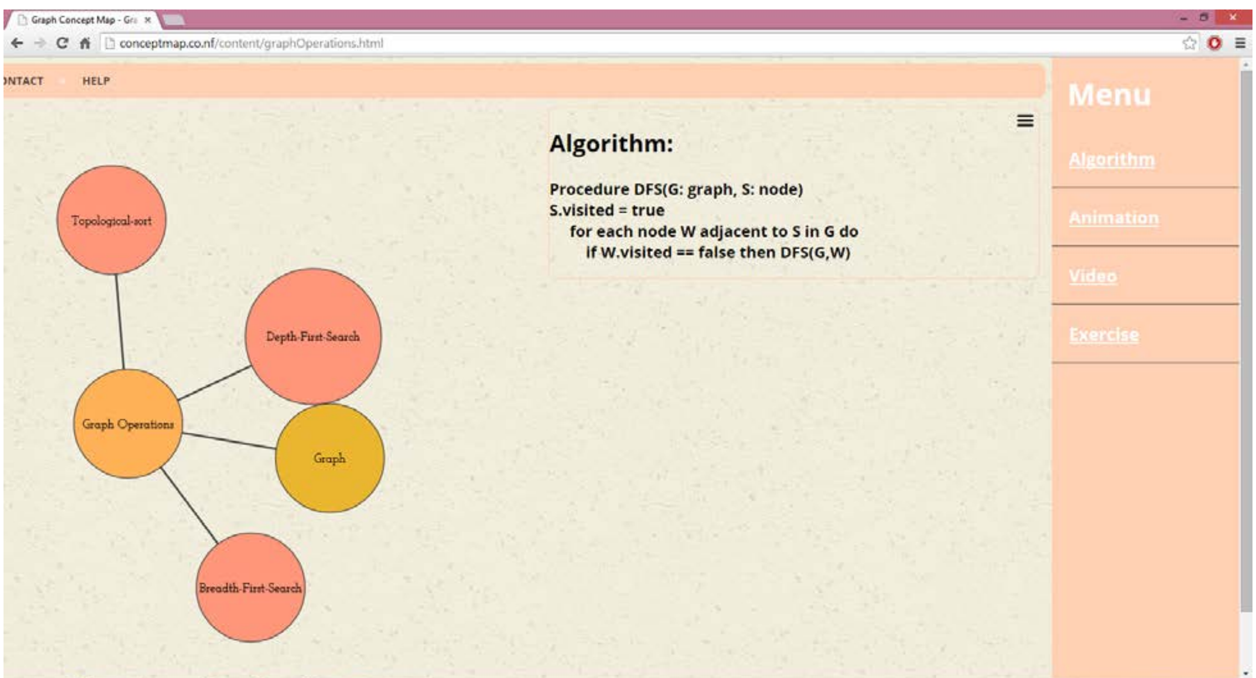

Graph Concept Map - Ho
conceptmap.co.nf
HOME
ABOUT
CONTACT
HELP
Graph Types
Graph
Graph Representation
Graph Components
Graph Operations
A graph is defined by two sets. The first is a set of nodes, which are more commonly called vertices in graph terminology. The second is a set of connections linking pairs of vertices, called edges. In general, graphs allow an edge to connect any pair of vertices. Trees and lists can be viewed as restricted forms of graphs, so graphs can be viewed as the most general of all data structures.
Explore the concept map on the left to learn more about different topics related to graph data structure and operations.

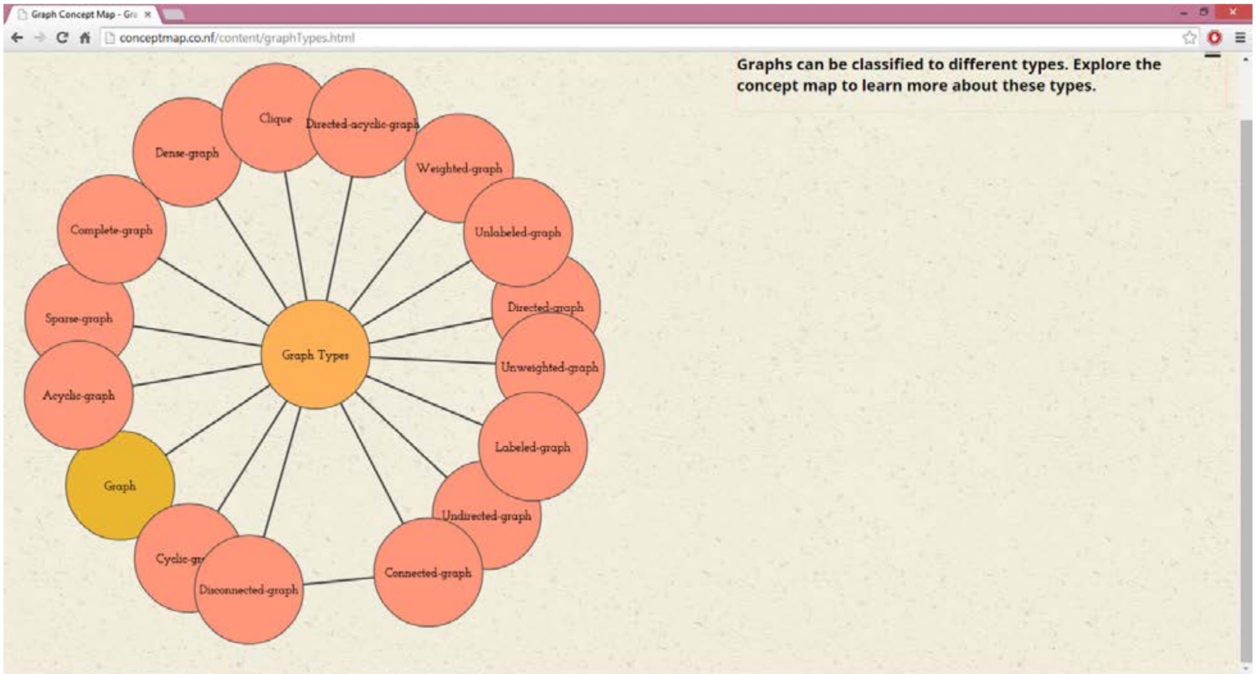

Graph Concept Map - Ab
conceptmap.co.nf/about.html
HOME
ABOUT
CONTACT
HELP
This project is developed as part of a master thesis and is funded by the NSF. The content on this site is taken from the following books:
• Introduction to Algorithms, Third Edition, Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein.
• A Practical Introduction to Data Structures And Algorithm Analysis, Java Edition, Clifford A. Shaffer.

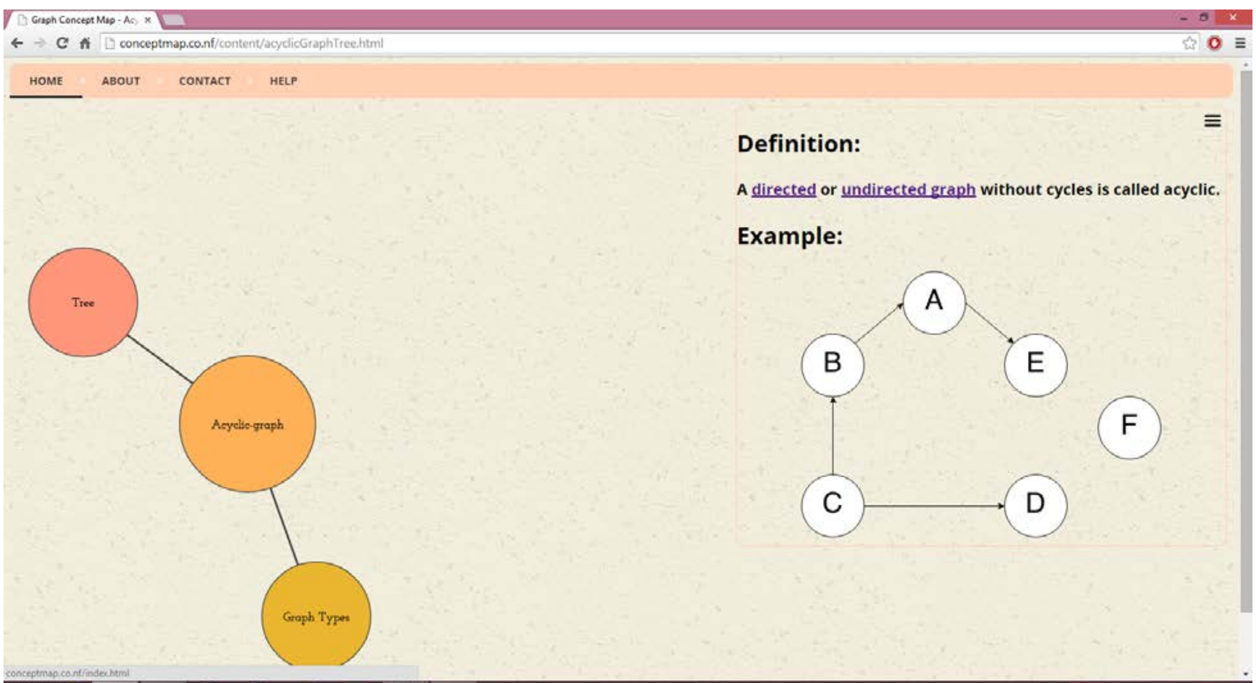

Graph Concept Map - Co
conceptmap.co.nf/contact.html
HOME
ABOUT
CONTACT
HELP
For any questions or inquiries, you can contact us:
Fatimah Aldubaisi, MS Student, CSSE Department, Auburn University.
fha0002@tigermail.auburn.edu

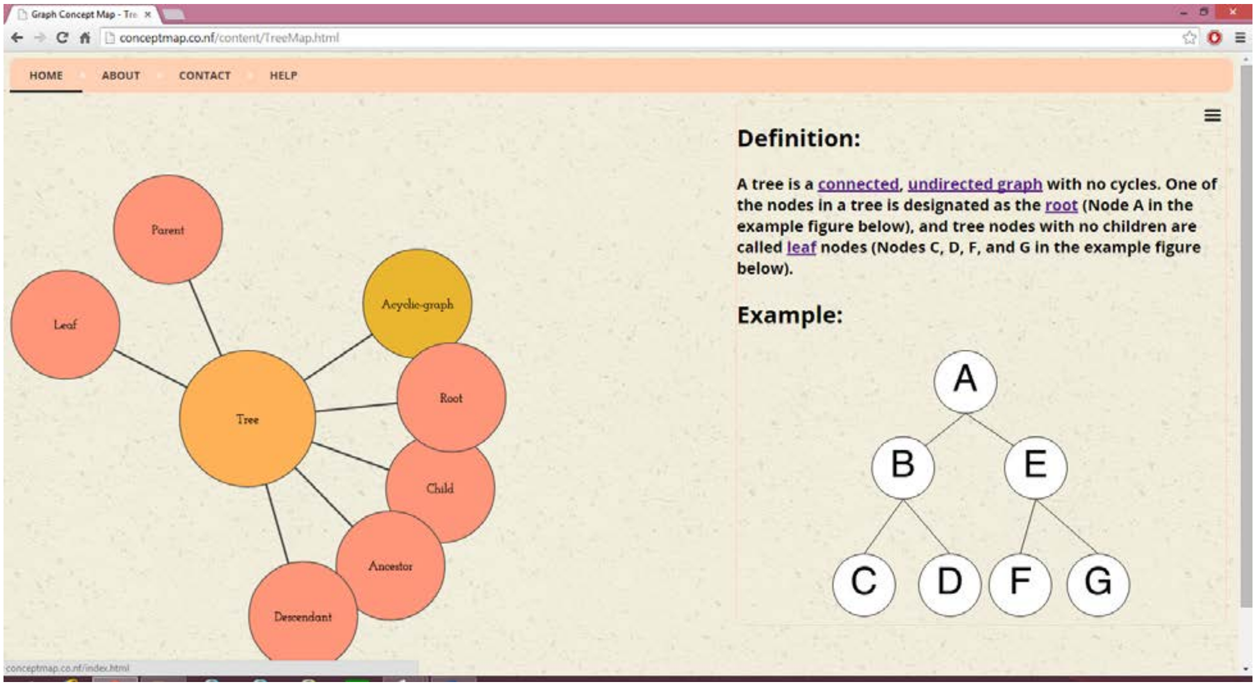

Graph Concept Map - He
conceptmap.co.nf/Help.html
HOME
ABOUT
CONTACT
HELP
The map on the left shows topics related to the graph data structure and associated algorithms. Clicking on a topic will display more information, such as its definition and illustrative examples, on the right side of the screen. If there are additional concepts related to the topic that you clicked, a new concept map showing those concepts will appear on the left; otherwise, the circle with the topic label will enlarge to show that you clicked on it.
There is a menu icon on the upper right corner. Clicking on it will bring up more options, such as viewing the pseudocode of an algorithm or opening a new page where an interactive animation of the algorithm can be accessed.


Graph Concept Map - Gra
conceptmap.co.nf/content/graphRepresentation.html
Adjacency-matrix
Graph
Graph Representation
Adjacency-list
Definition:
The adjacency-matrix representation of a graph G consists of a |V| X |V| matrix A = (aij) such that the entry in the ith row and the jth column in the matrix is a one if there is a directed edge from vertex i to vertex j of the graph, zero otherwise. If the edge has a weight associated with it, that weight appears on the matrix instead of one.
If the edge between vertex i and vertex j is undirected, then both the entry in the ith row and the jth column and the entry in the jth row and the ith column will be a one (or the edge weight). Therefore, the matrix representation for undirected graph will be a symmetric matrix.
Directed Graph Example:
1
2
3
4
5
6
The figure above shows a directed graph G with 6 vertices and

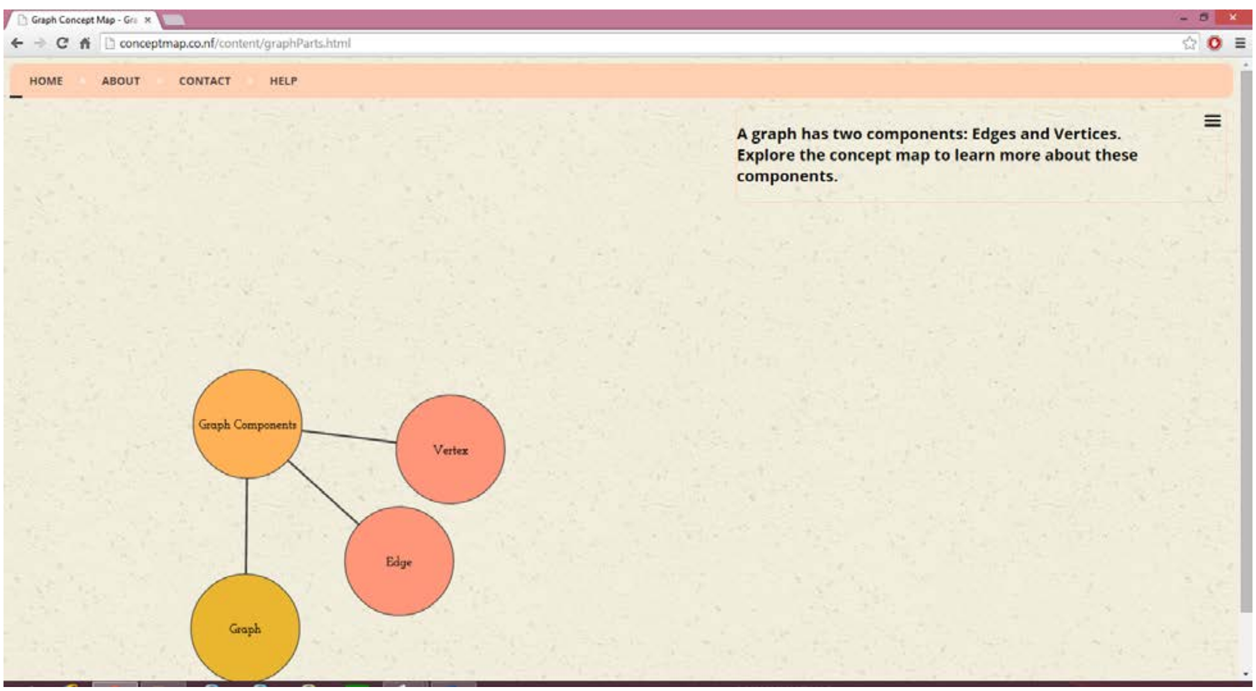

Graph Concept Map - Gra
conceptmap.co.nf/content/graphOperations.html
NTACT
HELP
Topological-sort
Depth-First-Search
Graph Operations
Graph
Breadth-First-Search
Algorithm:
Procedure DFS(G: graph, S: node)
S.visited = true
for each node W adjacent to S in G do
if W.visited == false then DFS(G,W)
Menu
Algorithm
Animation
Video
Exercise


Graph Concept Map - Gra
conceptmap.co.nf/content/graphTypes.html
Graphs can be classified to different types. Explore the concept map to learn more about these types.
Clique
Directed-acyclic-graph
Dense-graph
Weighted-graph
Complete-graph
Unlabeled-graph
Directed-graph
Sparse-graph
Graph Types
Unweighted-graph
Acyclic-graph
Labeled-graph
Graph
Undirected-graph
Connected-graph
Disconnected-graph

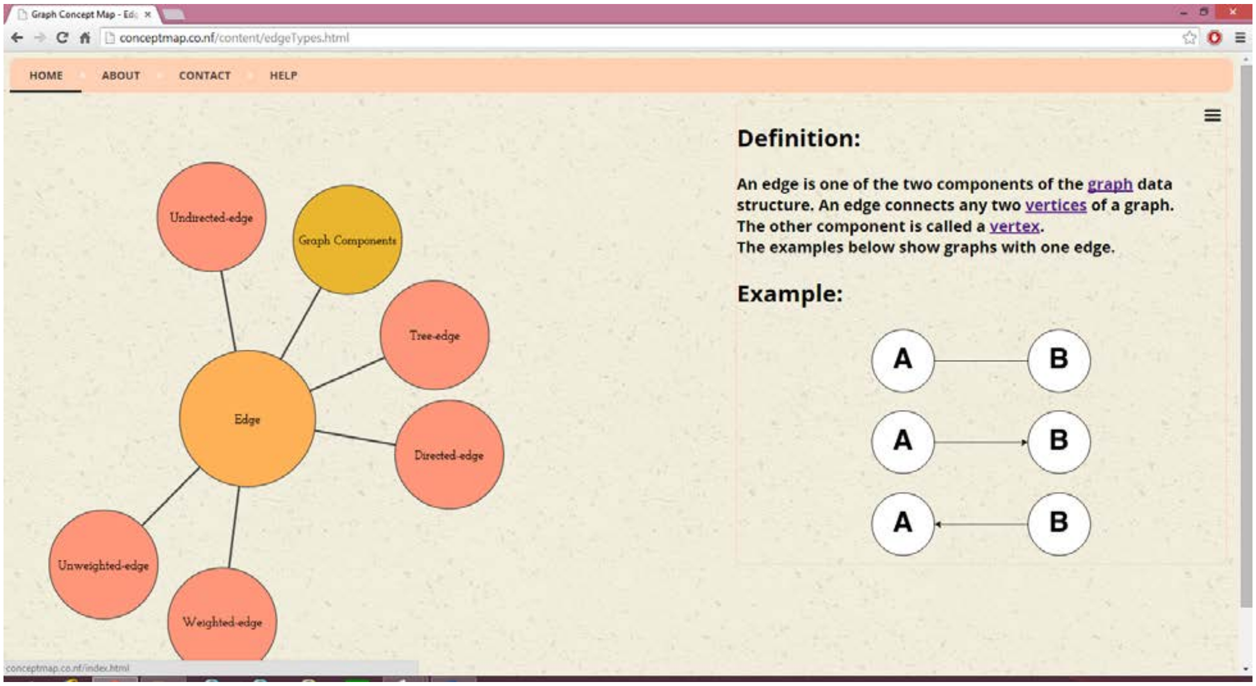

Graph Concept Map - Ac
conceptmap.co.nf/content/acyclicGraphTree.html
HOME
ABOUT
CONTACT
HELP
Definition:
A directed or undirected graph without cycles is called acyclic.
Example:
A
B
E
F
C
D
Tree
Acyclic-graph
Graph Types
conceptmap.co.nf/index.html



Graph Concept Map - Tre
conceptmap.co.nf/content/TreeMap.html
HOME
ABOUT
CONTACT
HELP
Definition:
A tree is a connected, undirected graph with no cycles. One of the nodes in a tree is designated as the root (Node A in the example figure below), and tree nodes with no children are called leaf nodes (Nodes C, D, F, and G in the example figure below).
Example:
A
B
E
C
D
F
G
Parent
Leaf
Acyclic-graph
Tree
Root
Child
Ancestor
Descendant
conceptmap.co.nf/index.html



Graph Concept Map - Gra
conceptmap.co.nf/content/graphParts.html
HOME
ABOUT
CONTACT
HELP
A graph has two components: Edges and Vertices. Explore the concept map to learn more about these components.
Graph Components
Vertex
Edge
Graph


Graph Concept Map - Ed
conceptmap.co.nf/content/edgeTypes.html
HOME
ABOUT
CONTACT
HELP
Undirected-edge
Graph Components
Tree-edge
Edge
Directed-edge
Unweighted-edge
Weighted-edge
Definition:
An edge is one of the two components of the graph data structure. An edge connects any two vertices of a graph.
The other component is called a vertex.
The examples below show graphs with one edge.
Example:
A
B
A
B
A
B
conceptmap.co.nf/index.html

Appendix B

Email Flyer, Demographic Data Questionnaire, and Consent Form

Email Flyer

E-Textbook Evaluation Research Study

You are invited to participate in a research study to evaluate the efficacy of an interactive electronic textbook (e-textbook) for data structures and algorithms, and to compare it with a traditional textbook. This study will take place in September 2014.

I am conducting this study as part of my Master's research in the CSSE department under the supervision of Dr. Narayanan. As a student registered in Section 1 of the course COMP 3270, you are eligible to participate in this study. Your participation in the study will require approximately an hour and a half of your time. Your participation would include the following activities:

(a) Signing the informed consent form. At this time you will have the opportunity to ask me any questions you have about this study, and decide whether you want to participate. (at most 15 minutes)
(b) Providing the demographics information listed below.
(c) Taking an online pre-knowledge survey to determine what you already know about the topic of graph data structures and algorithms. (about 15 minutes)
(d) Studying either an e-textbook chapter on this topic made available to you on a laptop or desktop (which I will provide) or a traditional textbook chapter (which I will provide). (about 30 minutes)
(e) Taking an online post-knowledge survey to determine what you newly learned about the topic of graph data structures and algorithms. (about 15 minutes)
(f) Completing a short online questionnaire about your opinions regarding the e-textbook you worked with and about traditional textbooks. (about 10 minutes)

Dr. Narayanan has agreed to count participation in this study in lieu of the Problem of the Day. Therefore, you can earn that assignment's 2.5% credit through participation. You may also choose a monetary compensation for your time ***($10 per hour rounded up to the next full hour***) instead, in which case (or if you choose not to participate) you will not be given the course credit without doing the assignment. Your participation will help me in my graduate work, potentially advance the design of interactive e-textbooks, and may benefit you by increasing your knowledge about graph data structures and algorithms, a topic covered in comp 3270.

I will not collect any identifiable data. All data will be stored and analyzed anonymously. You cannot be identified individually from any data collected from you, including any demographic information you provide. If you are willing to participate, please cut and paste the following demographic questions into a reply email, and email your answers to me AS SOON AS POSSIBLE. I will then correspond with you to schedule a time for the study that is convenient to you. It will take place in the HCI Lab (Shelby 2301/2302),

Thank you for volunteering!!
Fatimah Aldubaisi, MS Student, CSSE Department.

---DEMOGRAPHICS SURVEY
1. Your gender (1: male   2: female):
2. Your level (1:freshman   2: sophomore   3:junior   4:senior):
3. Your GPA range (1: zero to one   2: one to two   3: two to three   4: three to four):
4. Have you taken (or taking now) COMP 1210 FUNDAMENTALS OF COMPUTING I (yes/no)?
5. Have you taken (or taking now) COMP 2210 FUNDAMENTALS OF COMPUTING II (yes/no)?
6. Have you taken (or taking now) COMP 3270 INTRODUCTION TO ALGORITHMS (yes/no)?
7. Do you know how graphs are represented using other, simpler data structures (yes/no)?
8. Do you know the details of at least one graph algorithm (yes/no)?
9. Have you implemented or used a graph data structure in a program you wrote (yes/no)?
10. Have you implemented or used a graph algorithm in a program you wrote (yes/no)?
11. Overall, how much do you know about graph data structures and algorithms (1: no knowledge   2: a little knowledge   3:some knowledge   4: a lot of knowledge):

E-Textbook Evaluation Research Study

You are invited to participate in a research study to evaluate the efficacy of an interactive electronic textbook (e-textbook) for data structures and algorithms, and to compare it with a traditional textbook. This study will take place in September 2014.

I am conducting this study as part of my Master's research in the CSSE department under the supervision of Dr. Narayanan. As a graduate/undergraduate student in the CSSE department, you are eligible to participate in this study.

Your participation in the study will require approximately an hour and a half of your time. Your participation would include the following activities:

(a) Signing the informed consent form. At this time you will have the opportunity to ask me any questions you have about this study, and decide whether you want to participate. (at most 15 minutes)
(b) Providing the demographics information listed below.
(c) Taking an online pre-knowledge survey to determine what you already know about the topic of graph data structures and algorithms. (about 15 minutes)
(d) Studying either an e-textbook chapter on this topic made available to you on a laptop or desktop (which I will provide) or a traditional textbook chapter (which I will provide). (about 30 minutes)
(e) Taking an online post-knowledge survey to determine what you newly learned about the topic of graph data structures and algorithms. (about 15 minutes)
(f) Completing a short online questionnaire about your opinions regarding the e-textbook you worked with and about traditional textbooks. (about 10 minutes)

If you choose to participate in this study, as a "thank you" for your time and effort in helping me conduct this research, you will be offered ***$10 per hour rounded up to the next full hour*** Your participation will help me in my graduate work, potentially advance the design of interactive e-textbooks, and may benefit you by increasing your knowledge about graph data structures and algorithms.

I will not collect any identifiable data. All data will be stored and analyzed anonymously. You cannot be identified individually from any data collected from you, including any demographic information you provide.

If you are willing to participate, please cut and paste the following demographic questions into a reply email, and email your answers to me AS SOON AS POSSIBLE. I will then correspond with you to schedule a time for the study that is convenient to you. It will take place in the HCI Lab (Shelby 2301/2302),

Thank you for volunteering!!
Fatimah Aldubaisi, MS Student, CSSE Department.

---UNDERGRADUATE DEMOGRAPHICS SURVEY
1. Your gender (1: male 2: female):
2. Your level (1:freshman 2: sophomore 3:junior 4:senior):
3. Your GPA range (1: zero to one 2: one to two 3: two to three 4: three to four):
4. Have you taken (or taking now) COMP 1210 FUNDAMENTALS OF COMPUTING I (yes/no)?
5. Have you taken (or taking now) COMP 2210 FUNDAMENTALS OF COMPUTING II (yes/no)?
6. Have you taken (or taking now) COMP 3270 INTRODUCTION TO ALGORITHMS (yes/no)?
7. Do you know how graphs are represented using other, simpler data structures (yes/no)?
8. Do you know the details of at least one graph algorithm (yes/no)?
9. Have you implemented or used a graph data structure in a program you wrote (yes/no)?
10. Have you implemented or used a graph algorithm in a program you wrote (yes/no)?
11. Overall, how much do you know about graph data structures and algorithms (1: no knowledge 2: a little knowledge 3:some knowledge 4: a lot of knowledge):

---GRADUATE DEMOGRAPHICS SURVEY

1. Your gender (1: male 2: female):
2. Your level (1:Master's student 2: PhD student):
3. How many years have you been a CSSE graduate student? (1: 1 year or less 2: 2 years or less but more than one 3: 3 years or less but more than two 4: 4 years or less but more than three 5: more than 4 years):
4. Your GPA range (1: zero to one 2: one to two 3: two to three 4: three to four):
5. Have you taken (or taking now) a course on programming (yes/no)?
6. Have you taken (or taking now) a course on data structures (yes/no)?
7. Have you taken (or taking now) a course on algorithms (yes/no)?
8. Do you know how graphs are represented using other, simpler data structures (yes/no)?
9. Do you know the details of at least one graph algorithm (yes/no)?
10. Have you implemented or used a graph data structure in a program you wrote (yes/no)?
11. Have you implemented or used a graph algorithm in a program you wrote (yes/no)?
12. Overall, how much do you know about graph data structures and algorithms (1: no knowledge 2: a little knowledge 3:some knowledge 4: a lot of knowledge):

Consent Form

AUBURN UNIVERSITY
SAMUEL GINN COLLEGE OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE AND SOFTWARE ENGINEERING

(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMED CONSENT for a Research Study entitled
"E-Textbook Evaluation Study"

You are invited to participate in a research study to evaluate a new way of studying and learning about a new subject by using an e-textbook, and to compare it with traditional textbooks. The study is being conducted by Fatimah Aldubaisi from the Department of Computer Science & Software Engineering, under the supervision of Dr. N. Hari Narayanan from the Department of Computer Science & Software Engineering at Auburn University. You were selected as a possible participant because you are an undergraduate or a graduate student of the CSSE department, or a student registered for Section 1 of COMP 3270 in fall 2014.

What will be involved if you participate? If you decide to participate in this research study, you will be asked to take an online pre-knowledge survey to determine what you already know about the topic of graph data structures and algorithms (about 15 minutes). Then you will study either an e-textbook chapter on this topic made available to you on a laptop or desktop (which will be provided) or a traditional textbook chapter (which will be provided) (about 30 minutes). After that, you will take an online post-knowledge survey to determine what you newly learned about the topic of graph data structures and algorithms (about 15 minutes). Finally, you will complete a short online questionnaire about your opinions regarding the e-textbook you worked with and about traditional textbooks (about 10 minutes). All data will be collected confidentially and saved as anonymous data on a laptop that is in the possession of the PI. Your total time commitment will be approximately one hour and a half. **By agreeing to participate in this research study, you are consenting to allow the investigators to use the collected data for research purposes.**

Are there any risks or discomforts? The risks associated with participating in this study are minimal or non-existent.

Are there any benefits to yourself or others? By participating in the study, you can expect to gain a better understanding about the graph data structure and algorithms. However, we cannot promise you that you will receive any or all of these benefits.

Will you receive compensation for participating? To thank you, you will be offered 10$ per hour for your time rounded up to the next full hour upon the completion of your participation. If you are a student of COMP 3270 Section 1, you will have the option of accepting this monetary compensation, or instead opting for 2.5% course credit in lieu of the Problem of the Day assignment.

Are there any costs? No.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data will be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, or with those who are conducting this study and their academic departments.

Your privacy will be protected. All data collected from you will be saved and analyzed anonymously. Anonymous data may be kept indefinitely, shared with other researchers at participating institutions and the National Science Foundation, used to fulfill an educational requirement, published in journals, or presented at meetings.

If you have questions about this study, please ask them now or contact Fatimah Aldubaisi (tel: (318)278-9418; email: fha0002@auburn.edu). A copy of this document will be given to you to keep.

Participant's initials ______

107 Dunstan Hall • Auburn University, AL 36849-5347 • 334.844.4330 • Fax 334.844.6329 • www.eng.auburn.edu/csse/

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO PARTICIPATE.

Participant's signature Date	Investigator obtaining consent Date
Printed Name	Fatimah Aldubaisi Printed Name

The Auburn University Institutional Review Board has approved this document for use from 9/23/14 to 6/27/17 Protocol # 14-241 EX 1406

Appendix C

Usability Testing Collected Data

Recorded Notes

Usability Student #1:

- Asked if links on text shows the definition of concepts.
- Heading for the examples on graph representation (Directed graph example – Undirected graph example)
- Confused about the use of the terms nodes and vertices because test questions said nodes while materials referred to them as vertices.
- Used home link on the navigation bar at the top to go back to a previous page at first. Later on, student used the concept map to navigate.
- Suggested writing numbers as “1” and “0” instead of “one” and “zero”
- Suggested adding math formulas and concepts to the content, like the formula for counting the number of edges for linked-list representation and matrix representation. Also, writing that the matrix is symmetric for an undirected graph and mentioning matrix transpose. Student noted that the information is clear and understandable but it might be more helpful if the suggested information is added.
- Student looked for information related to the graph definition, but did not click on the concept node on the map. Looked through the system and then decided to find it later.
- Student was confused about “tree” concept and its position within the navigation. After some thought, student understood the relationships and why it was there.
- Student suggested editing the examples on the “ancestor” and “parent” concepts, saying that stating node “B” as a parent on one example and as an ancestor on another might confuse students.
- Student was confused about the label “graph operations”. Solved some questions without viewing it at first, then clicked on the node and asked why it was named as such and not “graph traversals”.

Usability Student #2:

- The student commented on the labels of “Tree (Graph Type)” node and “Tree (Edge Type)” and suggested that they do not have the same label.
- Student used the browser’s back button to go back or used “Home” link on the system
- Student did not notice that nodes change size at first and asked how to know which concept is clicked without looking at the text.
- Student asked if the nodes on graph types were alphabetically ordered.

Usability Student #3:

- Student did not find the concept “clique”. Viewed a lot of concepts and pages before asking for help about where to find it. Students commented that the concept map has a lot of concepts and students might not notice or see all of them, and suggested that concepts might be grouped together. Also, student asked if the concepts were ordered or if the order is changing.
- Student said the concept “graph representation” is a little confusing and suggested changing it to “graph representation with data structure”
- Student suggested adding links for the animation within the text to make them more accessible.

Usability Student #4:

- Student suggested that test questions be more randomized as the current order does not require going back to view the content because each question resembles the previous one.
- Student commented on the “graph types” map being jammed and cluttered and it will be better it was less crowded.
- Student had a problem finding the concept “clique” and asked for help but when encouraged to look again, student found the concept.

User Interface Evaluation Survey

Used for the usability testing and the actual testing

Please rate your satisfaction with the system

- **Try to respond to all items.**
- **For items that are not applicable, use: NA**

1. Overall reaction to the interface (terrible - wonderful)

0 (terrible)	1	2	3	4	5	6	7	8	9 (wonderful)	NA
○	○	○	○	○	○	○	○	○	○	○

2. Overall reaction to the interface (difficult - easy)

0 (difficult)	1	2	3	4	5	6	7	8	9 (easy)	NA
○	○	○	○	○	○	○	○	○	○	○

3. Overall reaction to the interface (frustrating - satisfying)

0 (frustrating)	1	2	3	4	5	6	7	8	9 (satisfying)	NA
○	○	○	○	○	○	○	○	○	○	○

4. Overall reaction to the interface (dull - stimulating)

0 (dull)	1	2	3	4	5	6	7	8	9 (stimulating)	NA
○	○	○	○	○	○	○	○	○	○	○

5. Overall reaction to the interface (rigid - flexible)

0 (rigid)	1	2	3	4	5	6	7	8	9 (flexible)	NA
○	○	○	○	○	○	○	○	○	○	○

1. Screen: Overall layout

0 (bad)	1	2	3	4	5	6	7	8	9 (good)	NA
○	○	○	○	○	○	○	○	○	○	○

2. Screen: The color scheme

0 (bad)	1	2	3	4	5	6	7	8	9 (good)	NA
○	○	○	○	○	○	○	○	○	○	○

3. Screen: Font style (size, color, ..)

0 (bad)	1	2	3	4	5	6	7	8	9 (good)	NA

4. Screen: Separation/ layout of the information with concept maps on the left and text on the right

0 (confusing)	1	2	3	4	5	6	7	8	9 (very clear)	NA

5. Screen: Sequence of screens

0 (confusing)	1	2	3	4	5	6	7	8	9 (very clear)	NA

6. Screen: Use of terms throughout the system

0 (inconsistent)	1	2	3	4	5	6	7	8	9 (consistent)	NA

Learning

1. Learning to use the system

0 (difficult)	1	2	3	4	5	6	7	8	9 (easy)	NA
○	○	○	○	○	○	○	○	○	○	○

2. Exploring features by trial and error

0 (difficult)	1	2	3	4	5	6	7	8	9 (easy)	NA
○	○	○	○	○	○	○	○	○	○	○

3. Navigation is straight forward

0 (never)	1	2	3	4	5	6	7	8	9 (always)	NA
○	○	○	○	○	○	○	○	○	○	○

4. Help menu item. (Check NA if you did not use it)

0 (Unhelpful)	1	2	3	4	5	6	7	8	9 (Helpful)	NA
○	○	○	○	○	○	○	○	○	○	○

Content

1. The concept map is helpful in understanding the relationships between graph concepts

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

2. The concept map is helpful in navigating the system

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

3. The information presented is useful

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

4. The information presented is interesting

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

5. The definitions of concepts are clear

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

6. The examples helped me understand concepts better

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

7. The animations helped me understand concepts better (Check NA if you did not look at animations)

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	NA
○	○	○	○	○	○

8. The algorithms helped me understand concepts better (Check NA if you did not view the algorithms)

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	NA
○	○	○	○	○	○

9. I gained new knowledge about graph data structure and algorithms from the system

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

10. I think the system helped me understand the concepts better than a textbook

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

If you have any other comments or notes, please write them down

Appendix D

Demographic Data Summary

Undergraduate Students Demographic Data Summary

Question 1:

Female	Male
3	18

Question 2:

Freshman	Sophomore	Junior	Senior
2	3	6	10

Question 3:

Zero to One	One to Two	Two to Three	Three to Four
0	1	5	15

Question 4:

Yes	No
21	0

Question 5:

Yes	No
21	0

Question 6:

Yes	No
15	6

Question 7:

Yes	No
11	10

Question 8:

Yes	No
8	13

Question 9:

Yes	No
6	15

Question 10:

Yes	No
6	15

Question 11:

No Knowledge	Little Knowledge	Some Knowledge	A lot of Knowledge
5	9	7	0

Graduate Students Demographic Data Summary

Question 1:

Female	Male
6	4

Question 2:

Master	PhD
5	5

Question 3:

1 year or less	2 years or less but more than one	3 years or less but more than two	4 years or less but more than three	more than 4 years
3	3	2	1	1

Question 4:

Zero to One	One to Two	Two to Three	Three to Four
0	0	0	10

Question 5:

Yes	No
9	1

Question 6:

Yes	No
9	1

Question 7:

Yes	No
10	0

Question 8:

Yes	No
7	3

Question 9:

Yes	No
8	2

Question 10:

Yes	No
7	3

Question 11:

Yes	No
6	4

Question 12:

No Knowledge	Little Knowledge	Some Knowledge	A lot of Knowledge
2	1	7	0

Appendix E

Actual Testing Collected Data

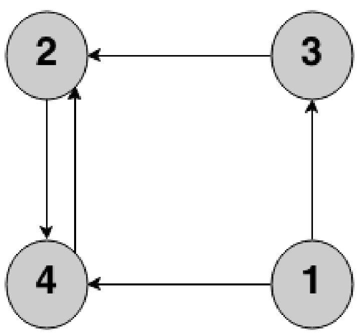
Pretest

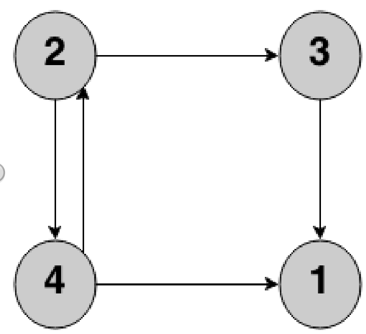
What is the maximum number of edges an undirected graph with 4 nodes can have?

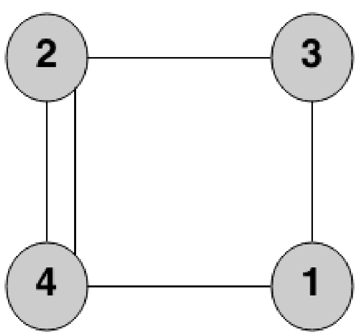
- 4
- 16
- 64
- 10
- None of the above

Which of the graphs below correspond to the adjacency matrix shown below?

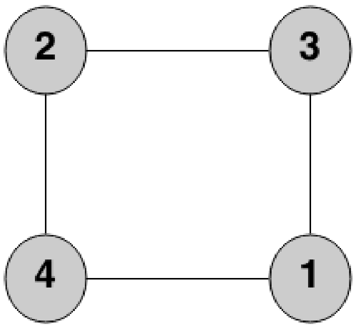
	1	2	3	4
1	0	0	1	1
2	0	0	1	1
3	1	1	0	0
4	1	1	0	0



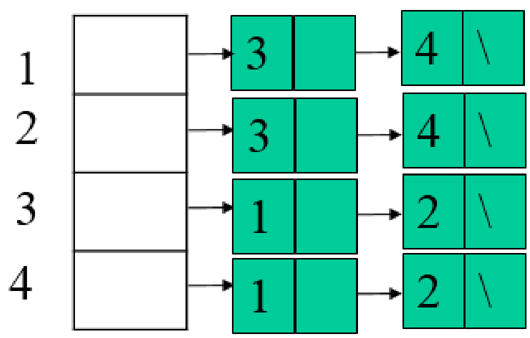


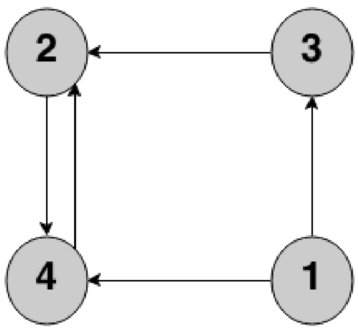


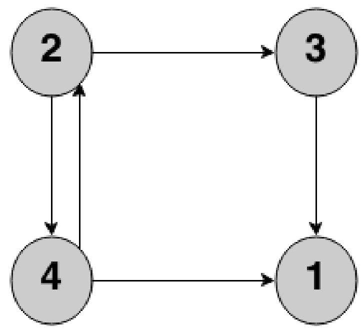
None of these graphs corresponds to the adjacency matrix.

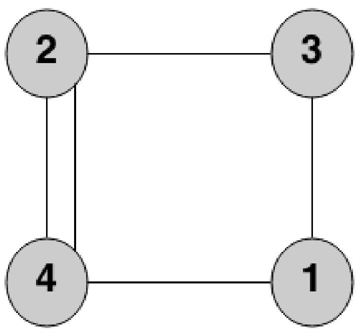


Which of the graphs below correspond to the adjacency list shown below?

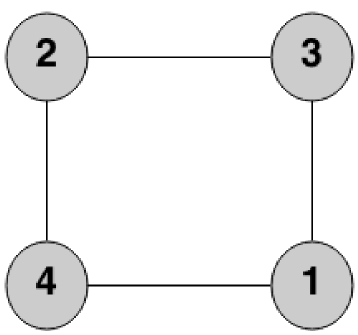








None of these graphs corresponds to the adjacency list.



Consider a graph with 10 nodes and 50 edges. How many linked lists will its adjacency list representation have?

- 50
- 100
- 10
- 60
- None of the above

Consider a graph with 10 nodes and 50 edges. How many total linked list nodes representing edges will its adjacency list representation contain if the graph is undirected?

- 50
- 100
- 10
- 60
- None of the above

Consider a graph with 10 nodes and 50 edges. How many total linked list nodes representing edges will its adjacency list representation contain if the graph is directed?

- 50
- 100
- 10
- 60
- None of the above

Consider a graph with 10 nodes and 50 edges. How many cells in its 10X10 adjacency matrix will have 1's in them if the graph is undirected?

- 50
- 60

- 100
- 10
- None of the above

Consider a graph with 10 nodes and 50 edges.
How many cells in its 10X10 adjacency matrix will have 1's in them if the graph is directed?

- 50
- 100
- 10
- 60
- None of the above

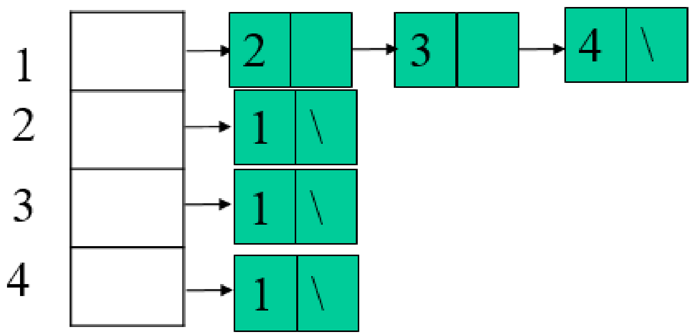
Is the graph represented by the adjacency matrix below a directed graph or an undirected graph?

	1	2	3	4
1	0	1	1	1
2	0	0	0	1
3	0	0	0	1
4	0	0	0	0

- Directed graph
- Undirected graph

I don't know

Is the graph represented by the adjacency list below a directed graph or an undirected graph?



Directed graph

Undirected graph

I don't know

True or False?

A

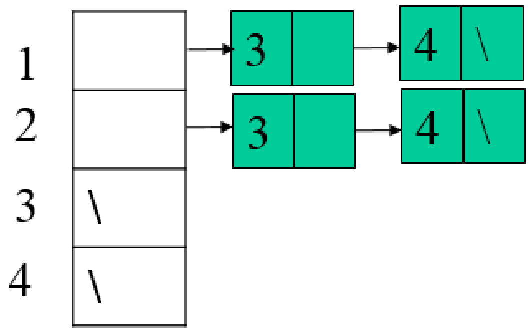
0	0	1	10
0	0	5	3
1	5	0	0
10	3	0	0

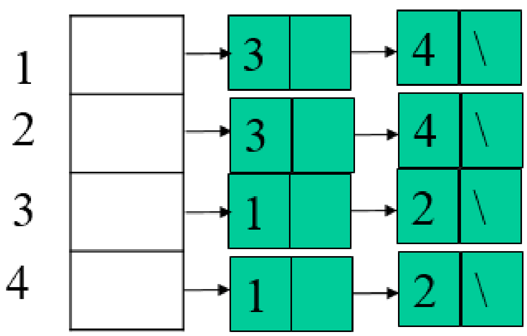
B

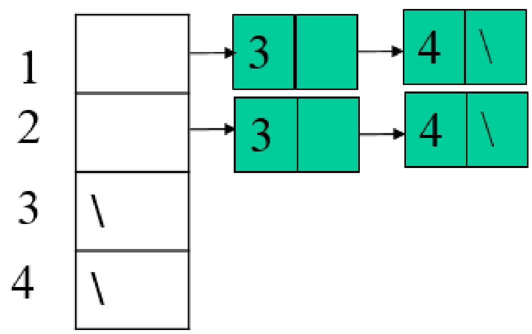
0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

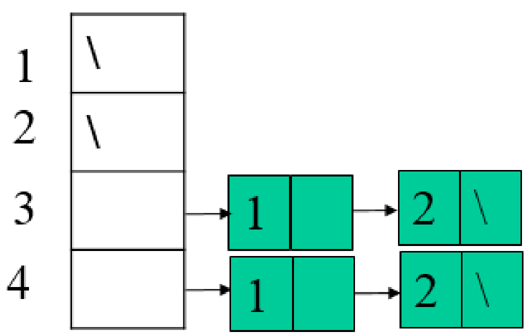
- [ ] Adjacency matrix A represents a weighted undirected graph
- [ ] Adjacency matrix B represents a unweighted directed graph

The graph represented by the adjacency list below is a directed graph. Suppose the directions (arrows) of all edges in this graph are reversed. Which of the adjacency lists below represents this reversed graph?

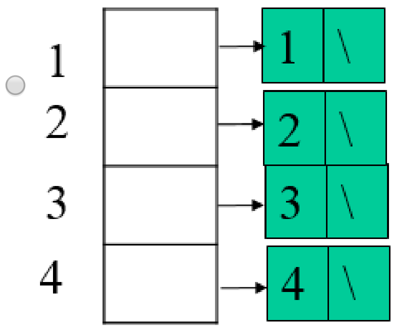








None of these lists corresponds to the reversed graph.



The graph represented by the adjacency matrix below <u>is a directed graph.</u> Suppose the <u>directions (arrows) of all edges in this graph are reversed</u>. Which of the adjacency matrices below represents this reversed graph?

	1	2	3	4
1	0	0	1	1
2	0	0	1	1
3	0	0	0	0
4	0	0	0	0

0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

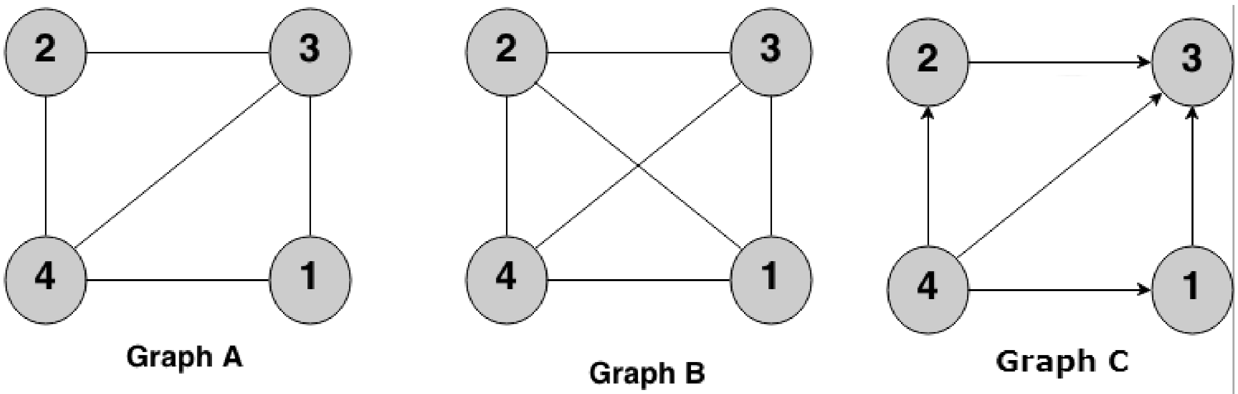
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

0	0	1	1
0	0	1	1
1	1	0	0
1	1	0	0

0	0	0	0
0	0	0	0
1	1	0	0
1	1	0	0

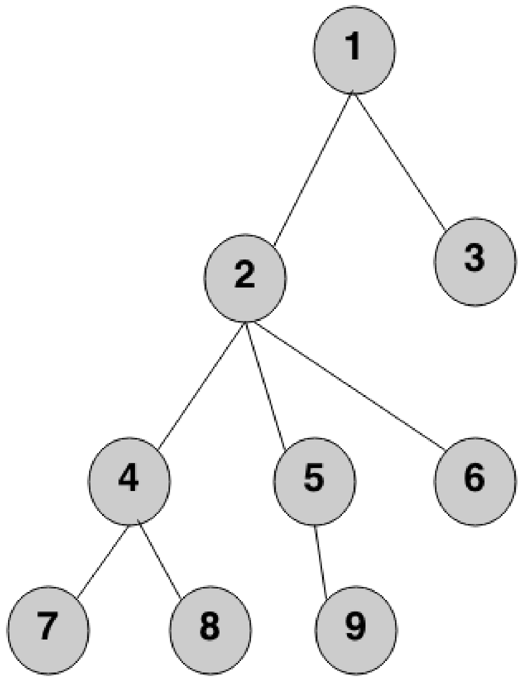
None of these matrices corresponds to the reversed graph.

True or False?



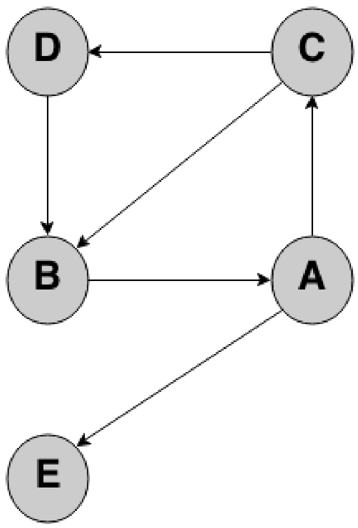
- Graph A is a complete graph
- Graph B is a complete graph
- Nodes 2, 3 & 4 in Graph A form a clique
- Graph B is a clique
- Graph C is a directed acyclic graph

True or False?



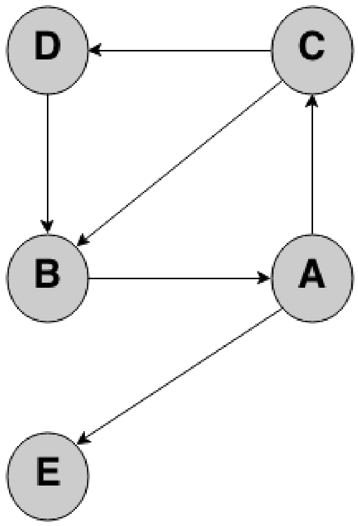
- Node 2 is an ancestor of node 9
- Node 7 is a descendant of node 5
- Node 3 is a child of node 1
- Node 2 is the parent of node 7
- Node 8 is a leaf

If the Depth-First Search algorithm starts on node C of the graph below, and if the recursive calls on adjacent nodes occur in the alphabetic order of the labels of those nodes, the next node the algorithm will visit is:



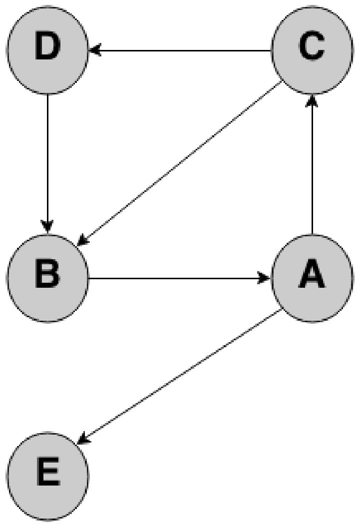
- node A
- node B
- node C
- node D
- node E

If the Depth-First Search algorithm starts on node C of the graph below, and if the recursive calls on adjacent nodes occur in the alphabetic order of the labels of those nodes, the order in which the algorithm will visit all the nodes is:



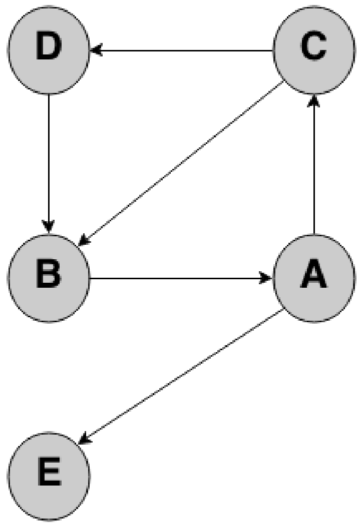
- C-B-A-E-D
- C-A-B-D-E
- C-A-D-B-E
- C-E-A-D-B
- None of the above

If the Breadth-First Search algorithm starts on node C of the graph below, and if the adjacent nodes are marked and added to the queue in the alphabetic order of the labels of those nodes, the next nodes the algorithm will add to the queue are:



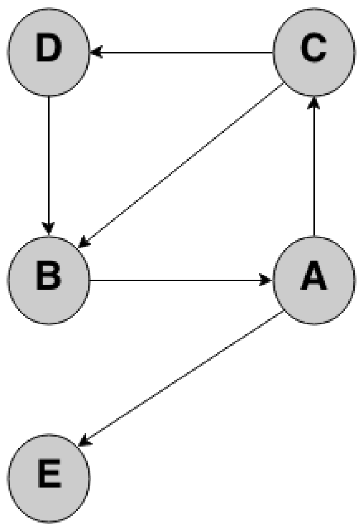
- nodes B & D
- nodes C & B
- nodes A & B
- nodes A, B & D
- nodes A & D

If the Breadth-First Search algorithm starts on node C of the graph below, and if the adjacent nodes are marked and added to the queue in the alphabetic order of the labels of those nodes, the order in which the algorithm will visit all the nodes is:



- C-B-A-D-E
- C-A-E-B-D
- C-D-B-A-E
- None of the above
- C-B-D-A-E

True or False?

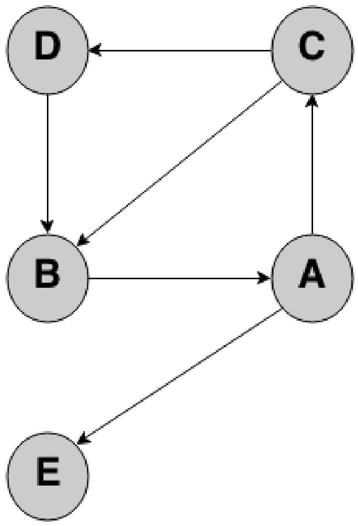


If the Breadth-First Search algorithm starts on node E of the graph above, it will not visit any other nodes.

Posttest

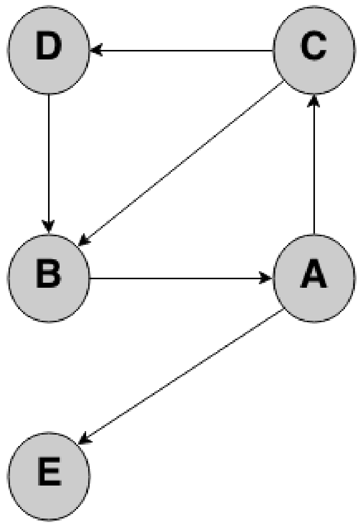
If the Depth-First Search algorithm starts on node A of the graph below, and if the

recursive calls on adjacent nodes occur in the alphabetic order of the labels of those nodes, the next node the algorithm will visit is:



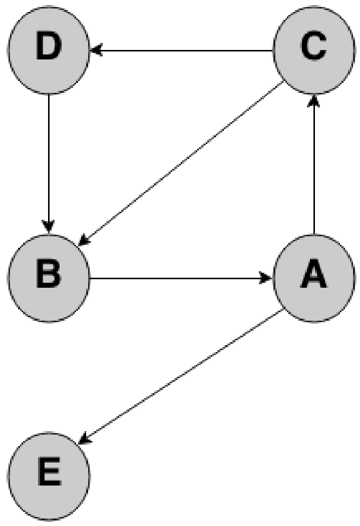
- node A
- node B
- node C
- node D
- node E

If the Depth-First Search algorithm starts on node A of the graph below, and if the recursive calls on adjacent nodes occur in the alphabetic order of the labels of those nodes, the order in which the algorithm will visit all the nodes is:



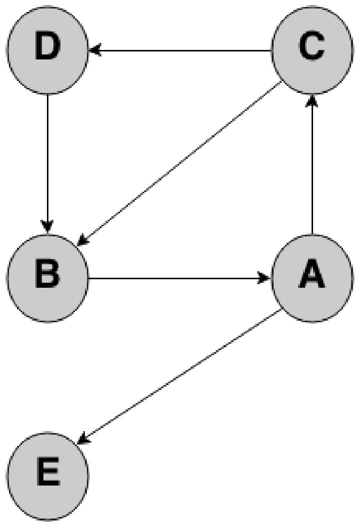
- A-B-C-D-E
- A-C-B-D-E
- A-C-D-B-E
- A-E-C-D-B
- None of the above

True or False?



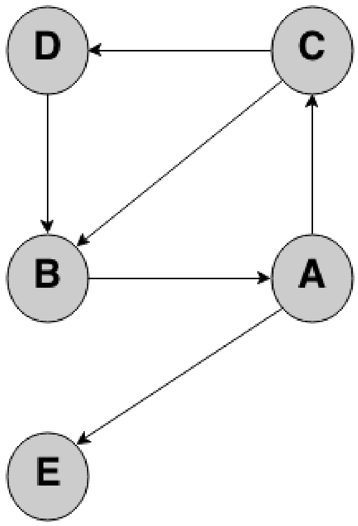
- [ ] If the Depth-First Search algorithm starts on node E of the graph above, it will not visit any other nodes.

If the Breadth-First Search algorithm starts on node A of the graph below, and if the adjacent nodes are marked and added to the queue in the alphabetic order of the labels of those nodes, the next nodes the algorithm will add to the queue are:



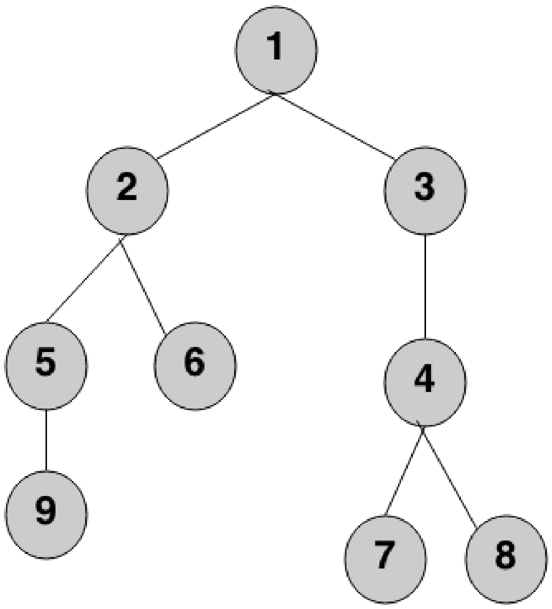
- nodes A & B
- nodes C & B
- nodes B & E
- nodes B, C & E
- nodes C & E

If the Breadth-First Search algorithm starts on node A of the graph below, and if the adjacent nodes are marked and added to the queue in the alphabetic order of the labels of those nodes, the order in which the algorithm will visit all the nodes is:



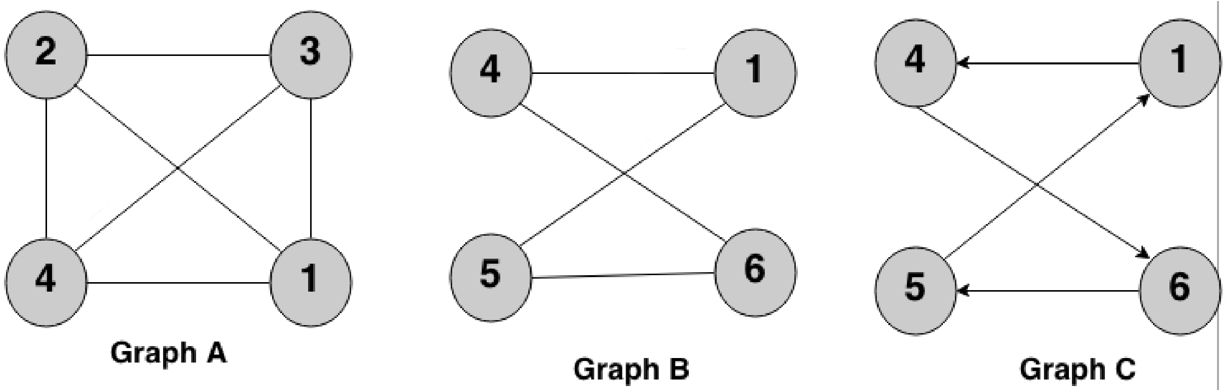
- A-B-C-D-E
- A-C-B-D-E
- A-C-D-B-E
- A-C-E-B-D
- None of the above

True or False?



- [ ] Node 2 is an ancestor of node 7
- [ ] Node 7 is a descendant of node 3
- [ ] Node 4 is a child of node 1
- [ ] Node 2 is the parent of node 5
- [ ] Node 5 is a leaf

True or False?



- Graph A is a complete graph
- Graph B is a complete graph
- Graph B is a clique
- Nodes 1, 4 & 5 in Graph B form a clique
- Graph C is an acyclic graph

The graph represented by the adjacency matrix below is a directed graph. Suppose the directions (arrows) of all edges in this graph are reversed. Which of the adjacency matrices below represents this reversed graph?

	1	2	3	4
1	0	0	0	0
2	0	0	0	0
3	1	1	0	0
4	1	1	0	0

-

0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

-

0	0	0	0
0	0	0	0
1	1	0	0
1	1	0	0

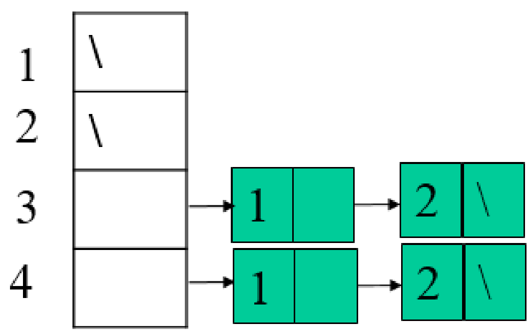
-

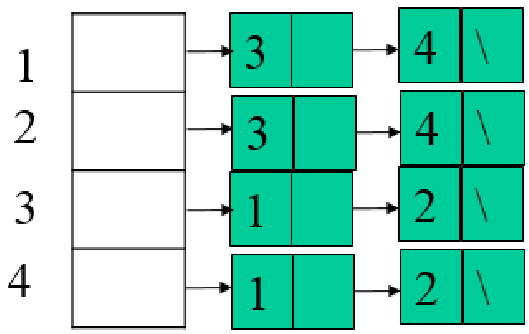
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

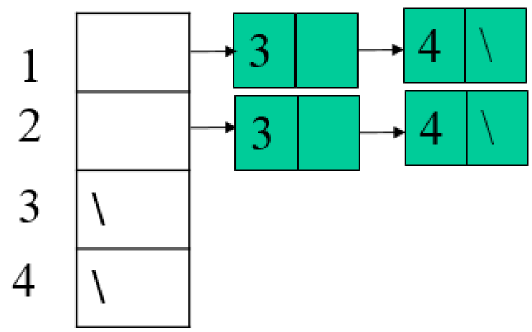
- None of these matrices corresponds to the reversed graph.

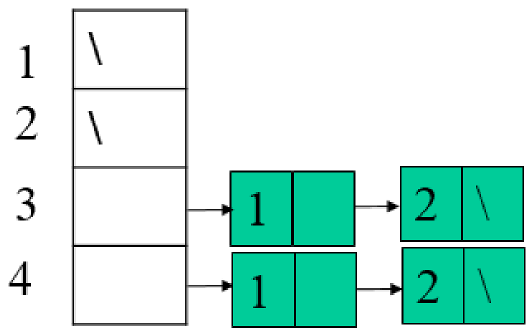
0	0	1	1
0	0	1	1
1	1	0	0
1	1	0	0

The graph represented by the adjacency list below <u>is a directed graph.</u> Suppose the <u>directions (arrows) of all edges in this graph are reversed</u>. Which of the adjacency lists below represents this reversed graph?

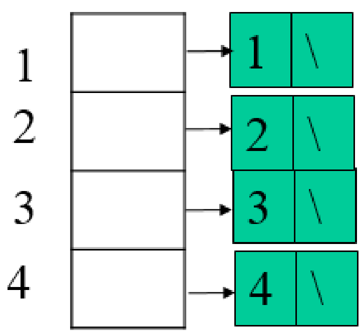








None of these lists corresponds to the reversed graph.



True or False?

A

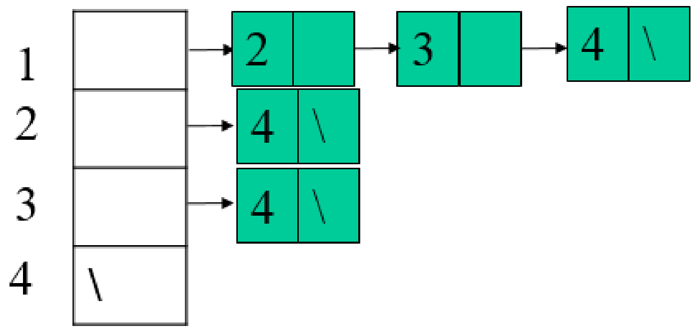
0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

B

0	0	0	0
0	0	0	0
1	5	0	0
10	3	0	0

- [ ] Adjacency matrix A represents an unweighted directed graph
- [ ] Adjacency matrix B represents a weighted undirected graph

Is the graph represented by the adjacency list below a directed graph or an undirected graph?



- ( ) Directed graph
- ( ) Undirected graph
- ( ) I don't know

Is the graph represented by the adjacency matrix below a directed graph or an undirected graph?

	1	2	3	4
1	0	1	1	1
2	1	0	0	0
3	1	0	0	0
4	1	0	0	0

- Directed graph
- Undirected graph
- I don't know

Consider a graph with 5 nodes and 25 edges.
How many cells in its 5X5 adjacency matrix will have 1's in them if the graph is directed?

- 30
- 25
- 50
- None of the above
- 5

Consider a graph with 5 nodes and 25 edges. How many cells in its 5X5 adjacency matrix will have 1's in them if the graph is undirected?

- 30
- 25
- 50
- None of the above
- 5

Consider a graph with 5 nodes and 50 edges. How many linked lists will its adjacency list representation have?

- 30
- 25
- 50
- None of the above
- 5

Consider a graph with 5 nodes and 25 edges. How many total linked list nodes representing edges will its adjacency list representation contain if the graph is directed?

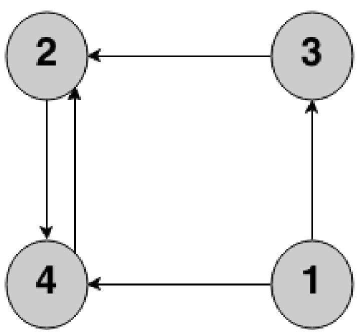
- 30
- 25
- 50
- None of the above
- 5

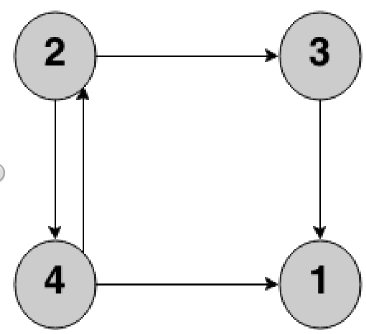
Consider a graph with 5 nodes and 25 edges. How many total linked list nodes representing edges will its adjacency list representation contain if the graph is undirected?

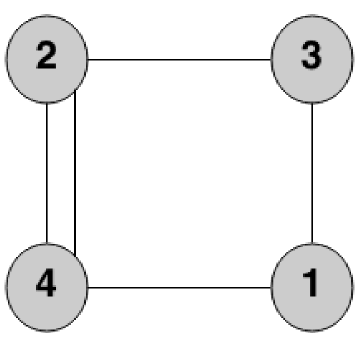
- 30
- 25
- 50
- None of the above
- 5

Which of the graphs below correspond to the adjacency matrix shown below?

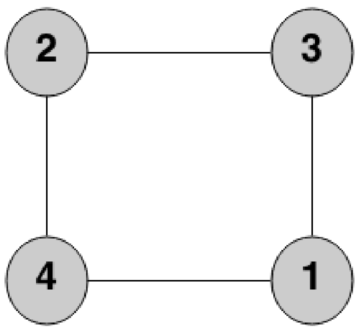
	1	2	3	4
1	0	0	1	1
2	0	0	0	1
3	0	1	0	0
4	0	1	0	0



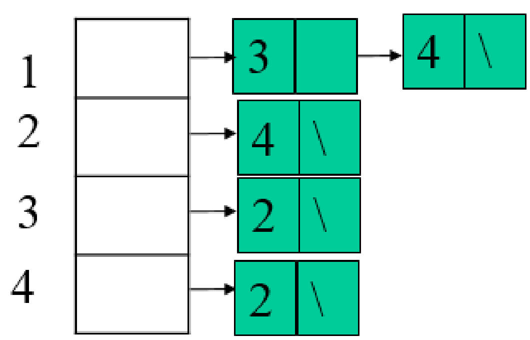


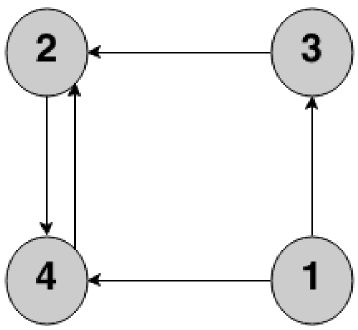


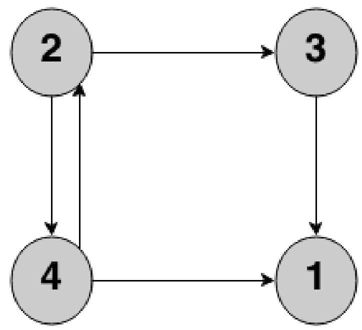
None of these graphs corresponds to the adjacency matrix.

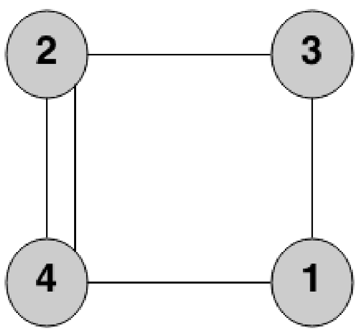


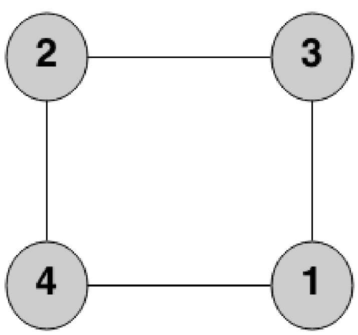
Which of the graphs below correspond to the adjacency list shown below?











None of these graphs corresponds to the adjacency list.

What is the maximum number of edges an undirected graph with 4 nodes can have?

- 10
- 16
- 64
- 4
- None of the above

3270 student TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	13	24	11
	24	27	3
	24	24	0
	15	24	9
	15	23	8
	24	27	3
	27	28	1
Average (mean)	**20.28571429**	**25.28571429**	**5**

other UG student TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	13	20	7
	28	27	-1
	16	22	6
Average (mean)	**19**	**23**	**4**

graduate student TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	16	22	6
	16	24	8
	16	20	4
	21	24	3
	13	24	11
Average (mean)	**16.4**	**22.8**	**6.4**

3270 student E-TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	15	24	9
	15	21	6
	14	21	7
	22	23	1
	26	27	1
	19	25	6
	22	28	6
	25	28	3
Average (mean)	**19.75**	**24.625**	**4.875**

other UG student E-TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	10	18	8
	18	27	9
	13	17	4
Average (mean)	**13.66666667**	**20.66666667**	**7**

graduate student E-TEXT group

	pretest score	posttest score	improvement=posttest - pretest
	28	28	0
	21	25	4
	27	29	2
	28	24	-4
	14	20	6
Average (mean)	**23.6**	**25.2**	**1.6**

UG student TEXT group

	pretest	posttest	improvement
	13	24	11
	24	27	3
	24	24	0
	15	24	9
	15	23	8
	24	27	3
	27	28	1
	13	20	7
	28	27	-1
	16	22	6
average	**19.9**	**24.6**	**4.7**

UG student E-TEXT group

pretest	posttest	improvement
15	24	9
15	21	6
14	21	7
22	23	1
26	27	1
19	25	6
22	28	6
25	28	3
10	18	8
18	27	9
13	17	4
18.09091	**23.54545**	**5.454545455**

Appendix F

Google Analytics Reports

Google Analytics

Graph Concept Map - http://conceptm… All Web Site Data [Go to this report]

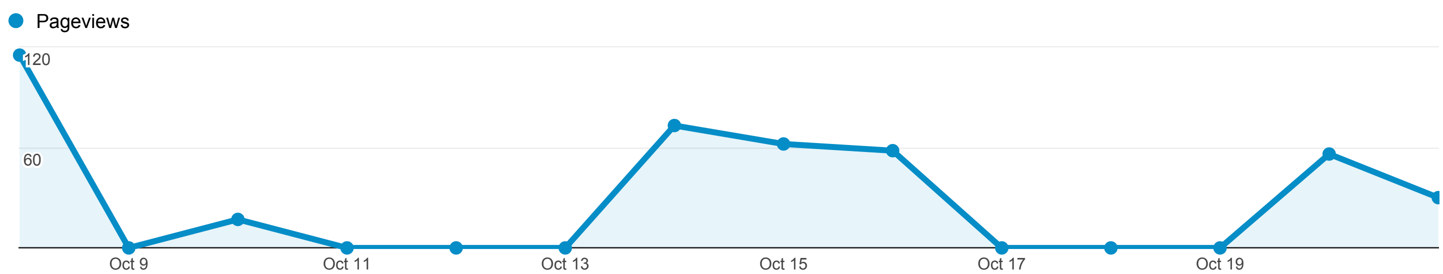
Pages

Oct 8, 2014 - Oct 21, 2014

All Sessions
100.00%

+ Add Segment

Explorer



	Page Title	Pageviews	Pageviews
		411 % of Total: 100.00% (411)	411 % of Total: 100.00% (411)
1.	Graph Concept Map - Home	146	35.52%
2.	Graph Concept Map - Graph Types	55	13.38%
3.	Graph Concept Map - Graph Components	53	12.90%
4.	Graph Concept Map - Graph Operations	40	9.73%
5.	Graph Concept Map - Acyclic Graph	35	8.52%
6.	Graph Concept Map - Graph Representation	31	7.54%
7.	Graph Concept Map - Edge	24	5.84%
8.	Graph Concept Map - Tree	15	3.65%
9.	Graph Concept Map - About	5	1.22%
10.	Graph Concept Map - Contact	4	0.97%

Rows 1 - 10 of 11

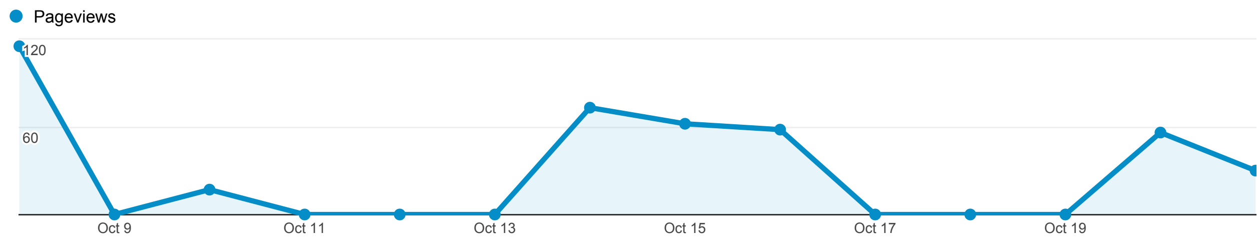
Pages

Oct 8, 2014 - Oct 21, 2014

All Sessions
100.00%

+ Add Segment

Explorer



	Page Title	Pageviews	Pageviews (compared to site average)
		411 % of Total: 100.00% (411)	411 % of Total: 100.00% (411)
1.	Graph Concept Map - Home	146	290.75%
2.	Graph Concept Map - Graph Types	55	47.20%
3.	Graph Concept Map - Graph Components	53	41.85%
4.	Graph Concept Map - Graph Operations	40	7.06%
5.	Graph Concept Map - Acyclic Graph	35	-6.33%
6.	Graph Concept Map - Graph Representation	31	-17.03%
7.	Graph Concept Map - Edge	24	-35.77%
8.	Graph Concept Map - Tree	15	-59.85%
9.	Graph Concept Map - About	5	-86.62%
10.	Graph Concept Map - Contact	4	-89.29%

Rows 1 - 10 of 11

Google Analytics

Graph Concept Map - http://conceptm… All Web Site Data [Go to this report]

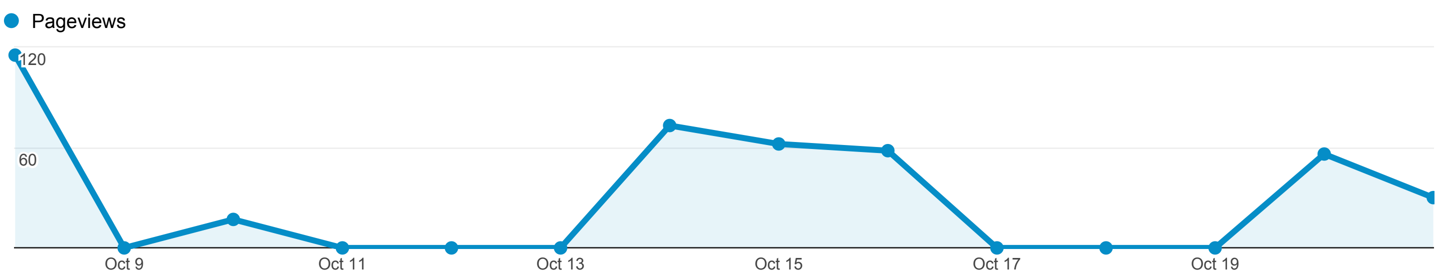
Pages

Oct 8, 2014 - Oct 21, 2014

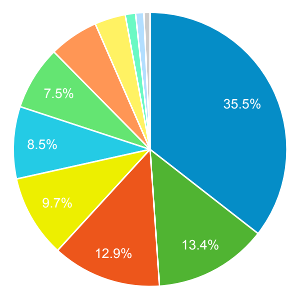
All Sessions
100.00%

+ Add Segment

Explorer



	Page Title	Pageviews	Pageviews	Contribution to total: Pageviews
		411 % of Total: 100.00% (411)	411 % of Total: 100.00% (411)	
1.	Graph Concept Map - Home	146	35.52%	
2.	Graph Concept Map - Graph Types	55	13.38%	
3.	Graph Concept Map - Graph Components	53	12.90%	
4.	Graph Concept Map - Graph Operations	40	9.73%	
5.	Graph Concept Map - Acyclic Graph	35	8.52%	
6.	Graph Concept Map - Graph Representation	31	7.54%	
7.	Graph Concept Map - Edge	24	5.84%	
8.	Graph Concept Map - Tree	15	3.65%	
9.	Graph Concept Map - About	5	1.22%	
10.	Graph Concept Map - Contact	4	0.97%	



Rows 1 - 10 of 11

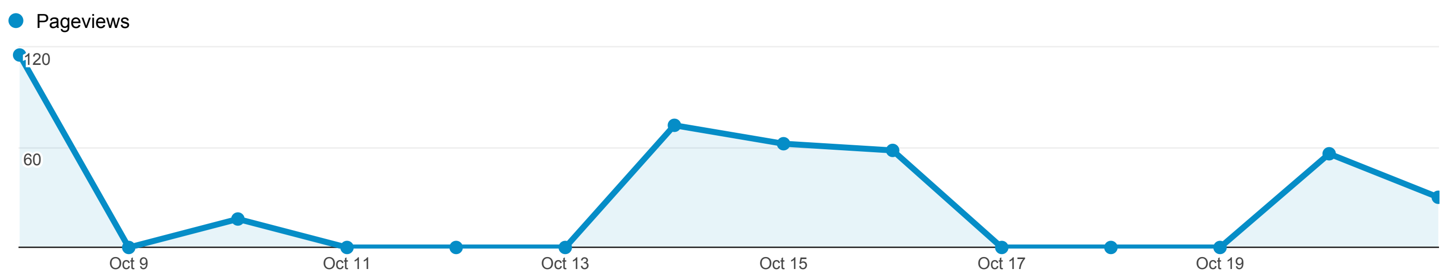
Pages

Oct 8, 2014 - Oct 21, 2014

All Sessions
100.00%

+ Add Segment

Explorer



	Page Title	Pageviews	Unique Pageviews	Avg. Time on Page	Entrances	Bounce Rate	% Exit	Page Value
		411 % of Total: 100.00% (411)	167 % of Total: 100.00% (167)	00:00:49 Site Avg: 00:00:49 (0.00%)	23 % of Total: 100.00% (23)	21.74% Site Avg: 21.74% (0.00%)	5.60% Site Avg: 5.60% (0.00%)	$0.00 % of Total: 0.00% ($0.00)
1.	Graph Concept Map - Home	**146** **(35.52%)**	42 (25.15%)	00:00:27	20 (86.96%)	10.00%	9.59%	$0.00 (0.00%)
2.	Graph Concept Map - Graph Types	**55** **(13.38%)**	19 (11.38%)	00:00:54	2 (8.70%)	100.00%	3.64%	$0.00 (0.00%)
3.	Graph Concept Map - Graph Components	**53** **(12.90%)**	20 (11.98%)	00:00:12	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
4.	Graph Concept Map - Graph Operations	**40** **(9.73%)**	19 (11.38%)	00:03:10	1 (4.35%)	100.00%	15.00%	$0.00 (0.00%)
5.	Graph Concept Map - Acyclic Graph	**35** **(8.52%)**	14 (8.38%)	00:00:13	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
6.	Graph Concept Map - Graph Representation	**31** **(7.54%)**	16 (9.58%)	00:01:46	0 (0.00%)	0.00%	3.23%	$0.00 (0.00%)
7.	Graph Concept Map - Edge	**24** **(5.84%)**	16 (9.58%)	00:00:34	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
8.	Graph Concept Map - Tree	**15** **(3.65%)**	10 (5.99%)	00:00:58	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
9.	Graph Concept Map - About	**5** **(1.22%)**	4 (2.40%)	00:00:08	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
10.	Graph Concept Map - Contact	**4** **(0.97%)**	4 (2.40%)	00:00:06	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)

Rows 1 - 10 of 11

Google Analytics

Graph Concept Map - http://conceptm...
All Web Site Data

Go to this report

Behavior Flow

Oct 8, 2014 - Oct 21, 2014

All Sessions
100.00%

+ Add Segment