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ASSERTION-EVIDENCE PRESENTATION APPROACH LEADS TO BETTER COMPREHENSION AND RETENTION OF COMPLEX TECHNICAL CONCEPTS

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ABSTRACT

This paper describes two experiments that compare students’ learning from a presentation that relies on the commonly practiced topic-subtopic slide structure versus students’ learning from a presentation that follows an assertion-evidence slide structure. In the topic-subtopic approach, the headline and body of the slide are heavily influenced by PowerPoint’s default outline structure. This structure consists of a topic-phrase headline supported either by a bulleted list of subtopics or by a bulleted list and a graphic. In the assertion-evidence structure, the heading is a succinct sentence assertion and the body of the slide supports that heading with visual evidence: photographs, drawings, diagrams, or graphs.

In each of the two experiments presented in this paper, two audiences heard the same recorded presentation, but one audience viewed topic-subtopic slides and another viewed assertion-evidence slides. The slide design differed between the two sets of slides in terms of different headlines, different amounts of text in the body, and different visual designs. The presentations presented background information about cancer and then explained the process of how magnetic resonance imaging can detect cancerous tumors. Students were tested immediately after the presentation and then again several days later.

In the first experiment, the increased understanding of the complex concept by the audience viewing the assertion-evidence slides was statistically significant (p<.001). This finding was reflected in the essay test results, as well as the short- and long-term retention tests. The overall averages were higher for the assertion-evidence group, but this difference was most emphasized in questions pertaining to primary details of the process presented. The assertion-evidence group also had fewer misconceptions about the process, which supports the hypothesis
that the assertion-evidence approach focuses the audience on main points of the presentation, rather than seductive details.

In the second experiment, the topic-subtopic slides contained more animations and better quality visual evidence quality than the topic-subtopic slides used in the first experiment. Both of these features more closely matched typical characteristics of the assertion-evidence approach. On the questions that tested for comprehension and retention of more complex concepts, students learning from the assertion-evidence slides scored higher than did students learning from topic-subtopic slides. However, unlike the first experiment, that difference was not statistically significant. While the size of that evidence was typically smaller, the auditorium in which the experiment occurred had a larger projected image than occurs in most rooms. Therefore, the design of visual evidence appears to have played a larger role in the comprehension of complex concepts than previously assumed. Because the visual evidence for the topic-subtopic slides were created using an assertion-evidence approach to slide design, the question arises as to whether the positive effect of explanatory graphics was able to offset negative effects on learning associated with other features of the topic-subtopic structure.

Also tested was the short-term and long-term recall of statistics and other factual information from the presentation. For more important facts that were included on both sets of slides (either as text or as visual evidence), the assertion-evidence participants had a recall that was as good as, or in several cases distinctly better, than participants viewing the topic-subtopic slides. That increase in recall can be attributed to those details being emphasized in the headline or in graphics on the assertion-evidence slides, as opposed to bulleted lists on the topic-subtopic slides. Not surprisingly, the topic-subtopic participants fared better with minor details—details that the assertion-evidence approach did not consider important enough to place on the slides. This potential interaction between slide structure and information recall raises the question of
whether the better recall of that less important information by the topic-subtopic group occurred at the expense of not remembering the primary details as well.
# TABLE OF CONTENTS

List of Figures ........................................................................................................................................... v
List of Tables .............................................................................................................................................. vi
Acknowledgments ...................................................................................................................................... vii
Chapter 1 Introduction ............................................................................................................................. 1
Chapter 2 Literature Review ...................................................................................................................... 4
Chapter 3 Methods .................................................................................................................................. 10
   Design ..................................................................................................................................................... 10
   Evaluation ............................................................................................................................................... 16
Chapter 4 Results and Discussion ........................................................................................................... 19
   Results for Post-Test Essay Question .................................................................................................. 19
   Results for the Short-Answer Post-Tests .............................................................................................. 22
Chapter 5 Conclusions and Recommendations ....................................................................................... 28
Appendix A: Script for Slides .................................................................................................................... 31
Appendix B: Essay Question ..................................................................................................................... 38
Appendix C: Rubrics for Scoring the Essay Test ...................................................................................... 39
Appendix D: Immediate Post-Tests .......................................................................................................... 43
Appendix E: Delayed Post-Tests ............................................................................................................... 47
References .................................................................................................................................................. 49
LIST OF FIGURES

Figure 1-1. Sample topic-subtopic slide and assertion-evidence slide.................................2

Figure 3-1. Sample slides from assertion-evidence presentation........................................12

Figure 3-2. Sample slides from the topic-subtopic presentation.........................................13
LIST OF TABLES

Table 2-1. Summary of research done in the field of multimedia presentation design .......... 7
Table 3-1. Categories of information presented in script ................................................. 14
Table 3-2. Characteristics of topic-subtopic and assertion-evidence slides ....................... 15
Table 3-3. Breakdown of questions on short-answer portion of immediate post-test .......... 18
Table 4-1. Results of essay test for assertion-evidence and topic-subtopic groups .......... 20
Table 4-3. Short-term recall for the first experiment ....................................................... 24
Table 4-4. Short-term recall for the second experiment ................................................. 25
Table 4-5. Long-term recall for the first experiment ..................................................... 26
Table 4-6. Long-term recall for the second experiment ................................................. 27
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Thanks are also due to Joanna Garner, Melissa Marshall, and Darrell Velegol. Dr. Garner is a member of our research group, and has provided much insight, especially in the statistical analyses of the data. Although we have yet to meet in person, she has assisted in designing, carrying out, and evaluating our experiments. Melissa first sparked my interests in technical communication through an introductory speech course and the Engineering Ambassadors program, and introduced me to Michael Alley when I expressed interest in research. As honors adviser and professor, Dr. Velegol has helped me to shape my education to fit my broad interests. This support was especially evident when he encouraged me to pursue a non-traditional thesis outside of my major field of study.

Lastly, I would like to thank my family and friends for their love and continued support throughout my undergraduate education.
Chapter 1

Introduction

In engineering conferences, meetings, and classrooms, presentation slides are often used to communicate key concepts and factual details. A recent sampling of several thousand slides from engineering and science revealed that almost two-thirds had a topic-phrase headline supported by a bulleted list of subtopics. Because slides are used so often by engineering educators to communicate research, to teach students, and to have students demonstrate what they have learned, the question arises how effective this topic-subtopic structure is, compared with other slide structures, for helping audiences understand and remember the information.

The two experiments described in this paper compared the comprehension and retention by audiences viewing a topic-subtopic slide design with the comprehension and retention by audiences viewing assertion-evidence slides. In the assertion-evidence structure, the heading is a succinct sentence assertion and the body of the slide supports that heading with visual evidence. Theoretically, from communication and cognitive psychology perspectives, the assertion-evidence slide structure should be more effective at fostering student learning. Examples of a common topic-subtopic slide and an assertion-evidence slide with similar content are given in Figure 1-1.
Figure 1-1. Sample topic-subtopic slide (top) and assertion-evidence slide (bottom) with defining characteristics labeled.
Two research questions arise from these experiments:

1) What is the effect of using an assertion-evidence presentation approach versus a topic-subtopic approach on the audience’s comprehension of complex technical concepts?

2) What is the effect of using an assertion-evidence presentation approach versus a topic-subtopic approach on the audience’s short- and long-term retention of complex technical concepts?

This paper describes the methods by which the experiments were designed and conducted, as well as the observed results. The paper draws two conclusions to the research questions and provides two recommendations about the effective use of the assertion-evidence model to maximize comprehension and retention of complex technical concepts.
Chapter 2

Literature Review

When Microsoft PowerPoint was created in 1990, it revolutionized the world of technical communication and soon became one of the most preferred presentation methods for industry, research, and education. However, when Gaskins and Austin first created the program, the outline-based slide default format was more of an afterthought. By the 25th anniversary of the creation of PowerPoint, this program held a whopping 95% of the market share for presentation software. Even though the abilities of software have changed much in the past 25 years, the default slide structure of PowerPoint has changed little. There are now many varied design options, but in essence, these slides still follow the default topic-subtopic bulleted outline structure. As shown by Alley and Neeley, this default format has become a matter of convenience for many presenters. Two-thirds of technical slides found in a survey of thousands followed the topic-subtopic structure: 40% phrase headline supported by a bulleted list and 26% phrase headline supported by a bulleted list and a graphic.

Interestingly, this default setting was not created based on research from cognitive psychology or educational perspectives. The default setting encourages a slide full of text, with little to no physical space left for graphics. Paivio’s work with dual code theory has shown that written and spoken words are processed by the same part of the brain, whereas visuals (graphs, diagrams, photographs, etc) are processed by a different part of the brain.

The work of John Sweller regarding the cognitive load theory proposes that there is a limited capacity of the human mind to process information. While intrinsic cognitive load is
dependent on content complexity, extraneous cognitive load is dependent on the way in which information is presented. The simultaneous exposure of the audience to both written words on the slides and spoken words of the presenters could result in lost focus of the audience as a result of cognitive overload.\textsuperscript{14} Sweller also shows that for audiences with little background knowledge, seductive or peripheral details can interfere with the audience members’ focus on main points.\textsuperscript{15} As a result, for successful communication, it is necessary for a presenter to prioritize main points and to be selective about the information included on a presentation slide. The cognitive overload theory also maintains that redundant information can lead to cognitive overload. In other words, a verbal explanation supported by explanatory graphics on a slide would be more practical than written text on a slide that is equivalent to the words being spoken. For this reason, Sweller’s work would lead one to expect that the risk of cognitive overload is less for a presentation following an assertion-evidence approach than one following a topic-subtopic approach.

Richard Mayer has been involved in much research shaping multimedia learning theory. The main principle of this research is that the audience response to a presentation accompanied by graphics is better than one that is not accompanied by graphics.\textsuperscript{16} Other work completed by Mayer has shown that coherence and signaling are also important factors in presentation approach.\textsuperscript{17,18} Coherence deals with focusing on key facts and eliminating unimportant low-level details and distractors. Signaling is the manner in which the organization of a presentation can communicate the hierarchy of details. Because of the large amount of text on topic-subtopic slides, unimportant seductive details can theoretically interfere with the audience’s understanding of the main points.

Statistician Edward Tufte has been one outspoken opponent of PowerPoint, claiming that presenters often create slides following the default format, without thinking about the audience.\textsuperscript{19} According to Tufte, with the common bulleted list structure, audiences can also lose the
relationships between ideas, leaving the audience with a disjointed understanding of a concept or process.\textsuperscript{20} The assertion-evidence approach would theoretically avoid these pitfalls by focusing the audience on the main idea in the assertion. Because the assertion is written as a full sentence, the connections between different elements of the assertion are typically also communicated.

Limited research has been carried out to research how people learn from multimedia presentations. The most prominent works in this field are summarized in Table 2-1. Information in the table includes the research group, presentation medium, size and composition of audience, and length of presentation. The table also shows whether participants were allowed to take notes or ask questions during the presentations, as well as the means by which participant performance was evaluated.
Table 2-1. Summary of research done in the field of multimedia presentation design.

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Medium</th>
<th>Audience</th>
<th>Length of Talk</th>
<th>Notes taken by students</th>
<th>Questions from students</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayer\textsuperscript{21}</td>
<td>multimedia presentation, narration</td>
<td>individual</td>
<td>under 3 min</td>
<td>no</td>
<td>no</td>
<td>short answer retention and transfer questions</td>
</tr>
<tr>
<td>Alley, Schreiber, et al.\textsuperscript{22}</td>
<td>assertion-evidence, topic-subtopic, live speaker</td>
<td>6x 200 people, science class</td>
<td>full class periods</td>
<td>yes, copies of slides</td>
<td>yes</td>
<td>final exam (60% of questions test experimental concepts)</td>
</tr>
<tr>
<td>Issa et al.\textsuperscript{23}</td>
<td>Mayer-inspired slides (some assertion headlines), live speaker</td>
<td>3x groups of 40 medical students</td>
<td>full class period</td>
<td>yes</td>
<td>yes</td>
<td>pre- and post-tests of open ended questions</td>
</tr>
<tr>
<td>Garner et al. 2011\textsuperscript{24}</td>
<td>assertion-evidence and topic-subtopic slides, narration</td>
<td>groups of 25 undergraduates</td>
<td>6 min</td>
<td>no</td>
<td>no</td>
<td>essay questions, immediate and delayed fill-in tests</td>
</tr>
<tr>
<td>Wolfe Thesis, Experiment 1</td>
<td>assertion-evidence and topic-subtopic slides, narration</td>
<td>groups of 25 undergraduates</td>
<td>7 min</td>
<td>no</td>
<td>no</td>
<td>essay questions, immediate and delayed fill-in tests</td>
</tr>
<tr>
<td>Wolfe Thesis, Experiment 2</td>
<td>assertion-evidence and topic-subtopic slides, narration</td>
<td>groups of 50 undergraduates</td>
<td>10 min</td>
<td>no</td>
<td>no</td>
<td>essay questions, immediate and delayed fill-in tests</td>
</tr>
</tbody>
</table>

In his experimental work,\textsuperscript{25} Mayer tested the effectiveness of multimedia learning by performing experiments on individual participants. These participant viewed 1-2 minute narrated multimedia presentations describing technical information. Examples of presentations used are
How Lightning Storms Develop, How Brakes Work, and How Pumps Work. No text was shown on the slides. Presentations all lasted less than three minutes, ranging from 30 seconds to 140 seconds. For these experiments, the slides were created to communicate only essential process steps, with no distracters or secondary details included.

Alley and Schreiber et al.\textsuperscript{26} did larger scale multimedia learning experiments at the Virginia Polytechnic Institute and State University. The participants in the study were undergraduate students enrolled in one of six 200-student introductory geosciences courses for non-majors. While the live speaker and instruction material remained the same, four sections viewed topic-subtopic slides and two sections viewed assertion-evidence slides, and presentations ran nearly the full class period. The multiple choice course exams were used to evaluate the performance of participants. The slide decks were also made available to the students after the class. As a university course offering, students were allowed to take notes and ask questions.

Issa et al.\textsuperscript{27} completed experimental work that falls between Mayer’s experimental work and the work of Alley, Schreiber et al. The slides used for the experiment closely followed Mayer’s multimedia learning principles, but some slides also included single sentence assertions. Participants were 130 third year medical school students, divided into groups of around 40. The presentation lasted a full class period and focused on shock. Unlike the Alley & Schreiber et al. work, this presentation was only used in a single class period, rather than a multiple classes. Having had similar backgrounds in education, all participants were considered to be equal coming into the study. Two of the groups watched the Mayer-inspired presentation, and one group viewed a traditional topic-subtopic presentation. Students were allowed to take notes and encouraged to ask questions. Using open-ended pre-tests and post-tests, retention and transfer was measured.

Early experiments in multimedia learning focused on long academic presentations or short instructional videos. However, Garner et al. began testing slide design for medium-length
presentations in 2010. For these experiments, the technical process of magnetic resonance imaging (MRI) was described using a presentation accompanied by a recorded narration. One condition used a topic-subtopic approach, and the other used the assertion-evidence approach. The participants for this experiment were around 100 undergraduates (50 per condition) of varied engineering disciplines. These engineering students had a similar background in introductory physics, chemistry, and math. The participants were not allowed to ask questions about the material or take notes on the presentation.

The experiments presented in this thesis are most similar to the Garner et al. experiment, with some notable differences. As in the Garner et al. experiment, assertion-evidence and topic-subtopic conditions were tested with recorded narrations, and the participants were not allowed to take notes or ask questions. However, the scripts for the two experiments presented in this thesis were slightly longer and more technically challenging. The second experiment ran about 10 minutes in length, which is similar to the length of many technical talks in conferences. Because of the large group setting, it was expected that distracters were present, as in a natural presentation scenario. As in the work of Garner et al., the evaluation consisted of an immediate essay test and short- and long-term retention tests. The first experiment had a multiple choice immediate post-test and a fill-in the blank delayed post-test, while the second experiment had fill-in tests for both the immediate and delayed post-tests.
Chapter 3

Methods

Design

To test the two research questions on the effects of slide design on comprehension and retention of technical concepts, we created two sets of presentation slides that followed a single recorded script for each experiment. For each experiment, one set followed the assertion-evidence approach, displaying a full-sentence assertion accompanied by large visual evidence. The other set for each experiment followed the topic-subtopic slide design of a phrase headline supported by bulleted subtopics and, on most slides, visual evidence. The first experiment contained 11 slides per presentation, and the second experiment contained 14 slides per presentation. Presented in Figure 3-1 are three slides from a topic-subtopic set, and presented in Figure 3-2 are three slides from an assertion-evidence set.

The scripts developed for these experiments were meant to interest the audience, while introducing a new and challenging technical concept: the process of Magnetic Resonance Imaging (MRI). Magnetic resonance imaging was a suitable topic for this experiment, because the process is typically not taught to undergraduates (who composed our test audience). The first presentation had a length of nearly 7 minutes, and the second experiment had a length of almost 10 minutes. A summary of information given in each experiment can be found in Table 3-1, and the full scripts can be found in Appendix A.
For each experiment, the script and first set of slides created followed the format of the assertion-evidence style, which is outlined in the literature. Because the assertion-evidence slides were created first, the visual evidence was also designed specifically for the assertion-evidence slide model. Every slide in the assertion-evidence presentation had at least one photograph, drawing, diagram, or graph. In addition, layering animation techniques were used to show the progression of process steps, which is a characteristic of the assertion-evidence approach. Text was limited to a two-line full-sentence assertion at the top of the slide and limited call-outs for the visual evidence in the slide’s body. Each text block in this condition was no more than two lines of text.

The second set of slides for each experiment was then created using the same script, following the commonly practiced topic-subtopic structure described by Garner et al. All slides fell into either the categories of topic-subtopic, which accounts for 40% of technical slides, or topic-subtopic-graphic, which accounts for 26% of technical slides.
When the RF wave ceases, the magnetic field forces atoms to realign and release energy.

Applied RF waves add energy to hydrogen atoms, causing some to fall out of alignment with the magnetic field.

Applying a magnetic field causes the spins of atoms in the body to be aligned parallel to the field.

Figure 3-1. Sample slides from assertion-evidence presentation about the process of magnetic resonance imaging. Note that each of these slides had an additional layer of visual evidence that animated in during the discussion of the slide. Shown here are the final layers.
When Gradient Magnets Turn Off

- Field from superconducting magnet realigns atoms with RF energy
- These atoms move to lower energy state and release RF wave
- Transceiver can detect these waves
- The frequency of RF wave depends on molecule containing the H atom

When RF Waves Are Applied

- Transceiver sends pulse of RF waves that targets hydrogen
- Hydrogen atoms: plentiful in body
  - Body is more than 55% water
- Some H atoms absorb enough energy to overcome magnetic field
  - These atoms in higher energy state

How the MRI Process Begins

- Atoms have spins, which normally point in random directions
- MRI patient is placed in strong magnetic field so that spins align with field
- Gradient magnets send counter-acting field to small cube (voxel)
  - Field significantly lower in this voxel

Figure 3-2. Sample slides from the topic-subtopic presentation about the process of magnetic resonance imaging. Note that in the second experiment, each of these slides had animation of bulleted points and images during the discussion of the slide. Shown here are the final layers.
Table 3-1. Categories of information presented in script of this presentation.

<table>
<thead>
<tr>
<th>Type</th>
<th>Example from script</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual steps in process</td>
<td>When the gradient magnets turn off, the field of the superconducting magnet takes over again and forces those atoms that had absorbed the radio frequency energy to realign parallel to the field.</td>
</tr>
<tr>
<td>Primary facts and statistics</td>
<td>Currently, the National Cancer Institute estimates that 1 in 2 people in the United States will develop a case of cancer in his or her lifetime.</td>
</tr>
<tr>
<td>Secondary facts and statistics</td>
<td>This magnetic field, on the order of 1.5 Teslas, is extremely strong.</td>
</tr>
</tbody>
</table>

As can be seen in Table 3-2, the topic-subtopic slides had a much higher average projected word count than the assertion-evidence slides. According to Garner et al., who looked at a sampling of slides from industry, conferences, and international PhDs, the average projected words per slide are about 40, which is consistent with the topic-subtopic slide design for these experiments.
Table 3-2. Characteristics of topic-subtopic and assertion-evidence slides for each experiment.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First Experiment Slides</th>
<th>Second Experiment Slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of slides</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Total number of words on slides</td>
<td>457</td>
<td>216</td>
</tr>
<tr>
<td>Average projected words per slide</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>Number of slides with relevant graphics</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Number of slides with animations</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Total number of animations of text</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total number of animations of graphics</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Total length of presentation (minutes)</td>
<td>6:51</td>
<td>6:51</td>
</tr>
<tr>
<td>Total number of words in spoken script</td>
<td>969</td>
<td>969</td>
</tr>
<tr>
<td>Spoken words per minute</td>
<td>141</td>
<td>141</td>
</tr>
</tbody>
</table>

Also, as mentioned, 64% and 71% of the topic-subtopic slides contained relevant visual evidence in the first and second experiment, respectively, which is substantially higher than the 55% found in the common practice.\(^{35}\) In addition, all slides in the topic-subtopic set explaining the main process steps of magnetic resonance imaging included at least one visual for both experiments. Moreover, there was significantly more animation used in the topic-subtopic slides for the second experiment. These animations were used primarily to animate bullet-points of text.

Finally, the question arose whether the topic-subtopic slides would utilize the same visual evidence as the assertion-evidence slides. For these experiments, the same visual evidence was used. In the second experiment, the variable of the full-sentence headline versus the phrase headline supported by bulleted list was isolated as much as possible. However, as is common for
topic-subtopic slides, this visual evidence was often considerably smaller in size to accommodate a bulleted list on the slide. In the second experiment, some animation was incorporated to bring in the bullet points as they were addressed in the script, but layering techniques like those used in the assertion-evidence approach were not included. These layering techniques are often not practical on topic-subtopic slides because the allotted area for graphics is typically too small for animated graphics to be effective.

In both experiments, the participants were undergraduate engineering students of varied disciplines. All students were beginning a sophomore-level speech course required for graduation. However, the experiments took place early in their respective semesters, before any discussion of visual aids occurred in the class. As engineering students of the Pennsylvania State University, all of these students had completed core classes such as introductory chemistry, physics, and calculus, which gave them sufficient background knowledge to understand the presentation. The students were randomly divided up into two groups. In the first experiment, 59 students viewed the topic-subtopic presentation and 51 students viewed the assertion-evidence presentation in a standard-sized classroom. For the second experiment, 48 viewed the topic-subtopic presentation, while 52 students viewed the assertion-evidence presentation. For the second experiment, both presentations were shown in the Cybertorium, a large lecture hall with a screen that provides a larger respective image than the average classroom on campus.

**Evaluation**

After the presentation, participants took part in a series of three post-tests. The first was an essay test that occurred immediately after viewing the presentation. This essay test asked the students to describe the process of MRI without any additional scaffolding. In essence, the essay test asked the participants to describe how the magnetic resonance imaging process works. The
exact wording of this essay question for each experiment can be found in Appendix B. Because this test provided no scaffolding details for the participants as a multiple choice question would, the essay test revealed much about the audience’s comprehension of the complex concepts presented. The essays were scored in a blind rating system using the rubrics found in Appendix C. In the scoring, specific point values were assigned to the steps of the process. Participants had to convey not only understanding of each step, but the correct order of steps as well.

The scoring also identified misconceptions, pertaining either to conceptual steps in the process or to background facts. For instance, a conceptual misconception would be thinking that the superconducting magnets turn off (in the MRI process, the superconducting magnets remain on the entire time). A background fact misconception would be confusing biological cells with atoms. The deductions for these misconceptions depended on their severity: major misconceptions receive higher deductions than minor misconceptions.

Immediately following the essay test, the students in both experiments completed a multiple-choice survey to gather information about the participants followed by an immediate recall test to monitor short-term recall of primary and secondary factual information. A breakdown of the types of questions asked is listed in Table 3-3. The multiple-choice survey asked for feedback regarding the difficulty of understanding the presentation, prior knowledge of the topic, and interest in the topic. The immediate post-test for the first experiment consisted of 12 multiple choice questions, whereas the test for the second experiment consisted of 10 fill-in-the-blank style questions. These immediate recall test questions can be found in Appendix D. The primary purpose of this post-test was to gauge immediate recall. This post-test also gave a benchmark against which the similar longitudinal post-tests could be compared.
Table 3-3. Breakdown of questions on short-answer portion of immediate post-test.

<table>
<thead>
<tr>
<th>Type of Question</th>
<th>Questions</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary facts and statistics</td>
<td>4</td>
<td>In the MRI process, what occurs in the patient’s body when the transceiver emits radio frequency waves?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a. The spins of some atoms align with the magnetic field</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. The spins of some atoms fall out of alignment with the magnetic field</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. The spins of some atoms, especially those in cancer cells, align with the magnetic field</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. The spins of some atoms, especially those in cancer cells, fall out of alignment with the magnetic field</td>
</tr>
<tr>
<td>Secondary facts and statistics</td>
<td>8</td>
<td>About what percentage of the human body is water?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a. 55 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. 65 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 75 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. 85 percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e. 95 percent</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary facts and statistics</td>
<td>6</td>
<td>Currently, the National Cancer Institute estimates that 1 in ___ people in the United States will develop a case of cancer in his or her lifetime.</td>
</tr>
<tr>
<td>Secondary facts and statistics</td>
<td>3</td>
<td>According to the script, the superconducting magnet of an MRI machine is typically ____ teslas.</td>
</tr>
</tbody>
</table>

Finally, four to five days after the initial viewing of the presentation, the students were asked during their class period to complete a longitudinal test. For both experiments, this delayed post-test was a fill-in-the-blank style assessment with questions similar to the immediate post test for the second experiment. In this unannounced test, long-term recall was analyzed. The tests consisted of 16 fill-in-the-blank questions for the first experiment and 8 fill-in-the-blank questions for the second experiment.
Chapter 4

Results and Discussion

To address the first research question, this section presents results from the essay question given immediately after the presentation. To answer the second research question, this section presents results from the two short-answer tests, one given immediately after the essay test and the other given several days later. In addition, for both experiments, we collected data regarding prior knowledge in the magnetic resonance imaging process to ensure that no group of participants had an advantage. On a scale of 1 (no prior knowledge of the topic) to 7 (already knew all material presented), the average prior knowledge was very similar between test groups. For the first experiment, the topic-subtopic group averaged 2.6 and the assertion-evidence group averaged 2.7. In the second experiment, the topic-subtopic group averaged 2.6, while the assertion-evidence group averaged 2.8. The differences for both experiments were not statistically significant.

Results for Post-Test Essay Question

Table 4-1 shows the results of the essay post-test for both experiments. The average content score reflects total points earned, without any deductions for misconceptions, while the overall score accounts for those deductions. For the second experiment only, the misconceptions were further broken down to major and minor process and background fact misconceptions. An example of a major process misconception would be that the superconducting magnet turned off
during the process, and an example of a minor process misconception would be that only hydrogen atoms would be affected by the magnetic field.

Table 4-1. Results of essay test for assertion-evidence and topic-subtopic groups.

<table>
<thead>
<tr>
<th>Evaluation Factor</th>
<th>First Experiment</th>
<th>Second Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assertion-</td>
<td>Topic-Subtopic</td>
</tr>
<tr>
<td></td>
<td>Evidence Score</td>
<td>Score</td>
</tr>
<tr>
<td>Mean overall score (reflects deductions)</td>
<td>9.2 (of 15)</td>
<td>6.3 (of 15) ***</td>
</tr>
<tr>
<td>Mean content score (points earned)</td>
<td>10.1 (of 14)</td>
<td>7.8 (of 14) ***</td>
</tr>
<tr>
<td>Mean deduction for misconceptions</td>
<td>0.9</td>
<td>1.5*</td>
</tr>
<tr>
<td>Major Process Misconceptions</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Major Background Fact Misconceptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Process Misconceptions</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Minor Background Fact Misconceptions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05  
**p<0.01  
***p<0.001

The results for the first experiment show a number of interesting results. These reveal that there is a statistically significant (p<0.001) increase in comprehension of complex technical concepts by nearly 20% for the group that viewed the assertion-evidence presentation. The assertion-evidence group average was 61%, while the topic-subtopic average was 42%. In addition, the number of essays containing at least one major misconception was tracked for each
condition. Over half of the essays produced by the topic-subtopic group contained one or more major misconceptions, while one-third of the essays produced by the assertion-evidence group contained these same major misconceptions. This finding supports the theoretical argument that seductive details in the bulleted lists on the topic-subtopic slides could draw the audience focus away from the main ideas. Furthermore, an average of 1.5 points was deducted per essay for the topic-subtopic group as a result of misconceptions, whereas the assertion-evidence group lost an average of 0.9 points per essay due to misconceptions.

The results of the second experiment also showed that the assertion-evidence group scored slightly higher on the essay test, although these results were not statistically significant. In addition, for the second experiment, to determine whether any differences existed among the participants who appeared to best understand the process, we analyzed the top scoring essays (total scores of 15+) from each category. Several results of this analysis stood out. On the rubric, a point value was established for each main point that should have been mentioned in the essay. From this, the first observation was that in the accumulation of points of the essays scoring 15+, the assertion-evidence group averaged only 0.72 missed steps per essay, while the topic-subtopic group averaged 1.22 missed steps per essay. This result indicates that those viewing the assertion-evidence presentation mentioned more parts of the process, but did not describe the parts mentioned in as much depth as the topic-subtopic viewers. From the data, it is also evident that nearly equal amounts of the deductions from the assertion-evidence content scores come from each of the four categories, whereas many of the topic-subtopic deductions come from major process misconceptions. Another distinguishing difference between the two groups of essays was the inclusion of diagrams and images. Five of the eleven top scoring assertion-evidence essays (46%) replicated at least one image from the slide show into their essay. On the other hand, only one of nine top-scoring topic-subtopic essays (11.1%) included similar figures. This result suggests that for the assertion-evidence participants, the visual evidence was interwoven to a
greater extent with the understanding. Finally, in comparing the number of misconceptions, 1.06 points were deducted on average per topic-subtopic essay, while only 0.59 points were deducted per assertion-evidence slide from the raw content score. Further analysis of those misconceptions is needed to determine whether these differences reveal any differences in understanding.

**Results for the Short-Answer Post-Tests.**

To address the second hypothesis, we conducted two post-tests for each experiment: one given immediately after the essay test (multiple choice for the first experiment and fill-in-the-blank for the second experiment) and a delayed post-test given several days later (fill-in-the-blank for both experiments). A summary of results for both experiments and both short-answer post-tests can be found in Table 4-2.

Table 4-2. Summary of short-answer post-test results for topic-subtopic (TS) slides and assertion-evidence (AE) groups in both experiments.

<table>
<thead>
<tr>
<th></th>
<th>First Experiment</th>
<th>Second Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AE Avg (%)</td>
<td>TS Avg (%)</td>
</tr>
<tr>
<td><strong>Immediate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Score</td>
<td>79</td>
<td>77</td>
</tr>
<tr>
<td>Primary details</td>
<td>75</td>
<td>58</td>
</tr>
<tr>
<td>Secondary Details</td>
<td>81</td>
<td>87</td>
</tr>
<tr>
<td><strong>Delayed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Score</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>Primary Details</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Secondary Details</td>
<td>59</td>
<td>54</td>
</tr>
</tbody>
</table>

*p<0.05
Table 4-3 shows the results of the multiple choice post-test administered after the first experiment. As is typical for a topic-subtopic presentation, the tested details occurred in the bulleted lists (subtopic list) on the slides. In the assertion-evidence structure, though, the presenter assigns a hierarchy to such details. The most important details are given in the sentence headline or included in the visual evidence. Secondary details are simply folded into the speech (the narration in this case). These differences are in the second and third columns of Table 4-3.

The assertion-evidence group consistently had higher scores for each question regarding a concept addressed in the headline of the slide. Questions 7 through 10 address the main process steps of MRI, the complex technical focus of the presentation. For these questions, the assertion-evidence group averaged 75% and the topic-subtopic group averaged 58%. The secondary details were not the focus of the presentation, but these questions asked the students to recall specific statistics from the presentation. For the secondary details represented on the slides with text or visual evidence, the assertion-evidence group tended to score as well as or higher than the topic-subtopic group. Because of the hierarchal nature of primary and secondary details in the assertion-evidence approach, this result indicates that the assertion-evidence audience understanding was better for the more important details, while the topic-subtopic group gained a better understanding of the secondary background details.
Table 4-3. Short-term recall for the first experiment: average scores on short-answer questions for background (green), primary (blue), and secondary (red) factual information of immediate post-test.

<table>
<thead>
<tr>
<th>Q</th>
<th>Representation on AE slides</th>
<th>Representation on TS slides</th>
<th>AE Avg (%)</th>
<th>TS Avg (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Secondary: Headline, visual evidence</td>
<td>In bulleted list</td>
<td>95%</td>
<td>82%</td>
</tr>
<tr>
<td>2</td>
<td>Secondary: Not on slides</td>
<td>In bulleted list</td>
<td>67%</td>
<td>76%</td>
</tr>
<tr>
<td>3</td>
<td>Secondary: Annotation, visual evidence</td>
<td>In bulleted list</td>
<td>70%</td>
<td>82%</td>
</tr>
<tr>
<td>4</td>
<td>Secondary: Diagram with text annotations</td>
<td>In bulleted list</td>
<td>83%</td>
<td>84%</td>
</tr>
<tr>
<td>5</td>
<td>Secondary: Not on slides</td>
<td>In bulleted list</td>
<td>60%</td>
<td>84%</td>
</tr>
<tr>
<td>6</td>
<td>Secondary: Not on slides</td>
<td>In bulleted list</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>7</td>
<td>Primary: In headline, visual evidence</td>
<td>In bulleted list, graphics</td>
<td>93%</td>
<td>90%</td>
</tr>
<tr>
<td>8</td>
<td>Primary: In headline, visual evidence</td>
<td>In bulleted list, graphics</td>
<td>77%</td>
<td>55%</td>
</tr>
<tr>
<td>9</td>
<td>Primary: In headline, visual evidence</td>
<td>In bulleted list, graphics</td>
<td>78%</td>
<td>55%</td>
</tr>
<tr>
<td>10</td>
<td>Primary: In headline, visual evidence</td>
<td>In bulleted list, graphics</td>
<td>53%</td>
<td>31%</td>
</tr>
<tr>
<td>11</td>
<td>Secondary: Not on slides</td>
<td>In bulleted list</td>
<td>97%</td>
<td>100%</td>
</tr>
<tr>
<td>12</td>
<td>Secondary: Visual Evidence</td>
<td>In bulleted list</td>
<td>88%</td>
<td>88%</td>
</tr>
</tbody>
</table>

Table 4-4 presents notable results for the post-test given immediately after the essay test in the second experiment. Overall, participants in the assertion-evidence group recalled the primary information as well as, or in some cases, better than participants in the topic-subtopic group recalled that information. That level of recall by the assertion-evidence group can be attributed to details being emphasized in the headline and in graphics. For every primary detail question with a statistically significant difference, the assertion-evidence group scored higher than the topic-subtopic group. Not surprising, the topic-subtopic participants fared better with
secondary details—details that the assertion-evidence approach did not consider important enough to place on the slides. The question arises, though, whether the better recall of that information by the topic-subtopic group occurred at the expense of not remembering the primary details as well.

Table 4-4. Short-term recall for the second experiment: average scores on short-answer questions for primary (blue) and secondary (red) factual information of immediate post-test.

<table>
<thead>
<tr>
<th>Q</th>
<th>Representation on AE slides</th>
<th>Representation on TS slides</th>
<th>AE Avg (%)</th>
<th>TS Avg (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary: headline and image</td>
<td>In bulleted list</td>
<td>92</td>
<td>79</td>
</tr>
<tr>
<td>2</td>
<td>Primary: Image</td>
<td>In bulleted list</td>
<td>79</td>
<td>81*</td>
</tr>
<tr>
<td>3</td>
<td>Primary: image</td>
<td>In bulleted list</td>
<td>83</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>Primary: image</td>
<td>In image and bulleted list</td>
<td>95</td>
<td>98*</td>
</tr>
<tr>
<td>5</td>
<td>Concept: headline, image</td>
<td>In bulleted list</td>
<td>95</td>
<td>100*</td>
</tr>
<tr>
<td>6</td>
<td>Primary: graph with number</td>
<td>In bulleted list</td>
<td>89</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>Primary: graph with number</td>
<td>In bulleted list</td>
<td>82</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>35</td>
<td>74</td>
</tr>
<tr>
<td>9</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>24</td>
<td>28*</td>
</tr>
<tr>
<td>10</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>45</td>
<td>75</td>
</tr>
</tbody>
</table>

*Not statistically significant

The results for the delayed post test revealed the same type of results in comparing the topic-subtopic group and assertion-evidence group. The longitudinal test results from the first experiment are shown in Table 4-5. In the first experiment, the assertion-evidence group scored higher on 14 of the 16 questions. The overall average score for the delayed test was 65% for the assertion-evidence group and 49% for the topic-subtopic group. On the two questions for which the topic-subtopic group scored higher, the difference was 2-3%.
Table 4-5. Long-term recall for the first experiment: average scores on short-answer questions for background (green), primary (blue), and secondary (red) factual information of delayed post-test.

<table>
<thead>
<tr>
<th>Question</th>
<th>Representation on AE slides</th>
<th>Representation on CP slides</th>
<th>AE Avg (%)</th>
<th>TS Avg (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Secondary: headline, image</td>
<td>In bulleted list</td>
<td>49%</td>
<td>21%</td>
</tr>
<tr>
<td>2</td>
<td>Secondary: annotation, image</td>
<td>In bulleted list</td>
<td>92%</td>
<td>94%</td>
</tr>
<tr>
<td>3</td>
<td>Secondary: annotation, image</td>
<td>In bulleted list</td>
<td>96%</td>
<td>94%</td>
</tr>
<tr>
<td>4</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>68%</td>
<td>45%</td>
</tr>
<tr>
<td>5</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>60%</td>
<td>45%</td>
</tr>
<tr>
<td>6</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>88%</td>
<td>65%</td>
</tr>
<tr>
<td>7</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>80%</td>
<td>61%</td>
</tr>
<tr>
<td>8</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>67%</td>
<td>44%</td>
</tr>
<tr>
<td>9</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>74%</td>
<td>42%</td>
</tr>
<tr>
<td>10</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>14%</td>
<td>17%</td>
</tr>
<tr>
<td>11</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>69%</td>
<td>48%</td>
</tr>
<tr>
<td>12</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>49%</td>
<td>36%</td>
</tr>
<tr>
<td>13</td>
<td>Primary: headline, image</td>
<td>Image, bulleted list</td>
<td>81%</td>
<td>60%</td>
</tr>
<tr>
<td>14</td>
<td>Secondary: headline, graph</td>
<td>In bulleted list</td>
<td>51%</td>
<td>48%</td>
</tr>
<tr>
<td>15</td>
<td>Secondary: headline, graph</td>
<td>In bulleted list</td>
<td>62%</td>
<td>40%</td>
</tr>
<tr>
<td>16</td>
<td>Secondary: headline, graph</td>
<td>In bulleted list</td>
<td>47%</td>
<td>26%</td>
</tr>
</tbody>
</table>
As shown in Table 4-6, in the second experiment, participants viewing the assertion-evidence slides had similar recall pertaining to primary statistics, as compared with participants viewing the topic-subtopic slides. Likewise, participants viewing the topic-subtopic slides were able to recall details that were secondary (or less important) better than participants viewing the assertion-evidence slides. Again, the question arises whether the better recall of that information by the topic-subtopic group occurred at the expense of not remembering the primary details as well.

Table 4-6. Long-term recall for the second experiment: average scores on short-answer questions for primary (blue) and secondary (red) factual information of delayed post-test.

<table>
<thead>
<tr>
<th>Question</th>
<th>Representation on AE slides</th>
<th>Representation on CP slides</th>
<th>AE Avg (%)</th>
<th>TS Avg (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary: headline, image</td>
<td>In bulleted list</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>Primary: image</td>
<td>In bulleted list</td>
<td>50</td>
<td>53*</td>
</tr>
<tr>
<td>3</td>
<td>Primary: image</td>
<td>In bulleted list</td>
<td>69</td>
<td>66*</td>
</tr>
<tr>
<td>4</td>
<td>Primary: headline image</td>
<td>Image, bulleted list</td>
<td>82</td>
<td>89</td>
</tr>
<tr>
<td>5</td>
<td>Primary: graph with number</td>
<td>In bulleted list</td>
<td>74</td>
<td>78*</td>
</tr>
<tr>
<td>6</td>
<td>Primary: graph with number</td>
<td>In bulleted list</td>
<td>66</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>8</td>
<td>Secondary: not on slides</td>
<td>In bulleted list</td>
<td>35</td>
<td>52</td>
</tr>
</tbody>
</table>

*Not statistically significant
Chapter 5

Conclusions and Recommendations

These experiments led to two main conclusions and two recommendations. The first conclusion drawn from these experiments was drawn from the immediate essay post-test results. In the first experiment, there was a clear difference in comprehension in favor of the assertion-evidence approach that was statistically significant (p<0.001).

Conclusion 1: A positive trend occurred for the assertion-evidence slides leading to better comprehension of complex concepts.

Similarly, the results of the second experiment showed a slight positive trend, but unlike the first experiment, this difference was not statistically significant. The participants viewing the topic-subtopic slides in this experiment fared much better than in the first, which arose from a combination of two possibilities.

One possible reason that the topic-subtopic group fared better in the second experiment is that these slides included much more animation of text and images than the first experiment. Because fewer new words were introduced at a single time on the slide, the audience might have been less likely to experience cognitive overload. Given that, it would be interesting to isolate this variable in a test to determine whether animation of bulleted items and images on the commonly-practiced topic-subtopic slides increases comprehension for a presentation of this type.

Another possible reason for the increased scores by the topic-subtopic participants in the second experiment had to do with the visual evidence used for the topic-subtopic slides. In both experiments, for all 8 slides presenting the complex concept of how magnetic resonance imaging works, the visual evidence had the same design as in the assertion-evidence slides. By nature of the topic-subtopic approach, this visual evidence is typically smaller to allow space for a bulleted
list. The visual evidence designed for the assertion-evidence slides were also used in the topic-subtopic slides for both experiments. However, for the second experiment, the auditorium in which the experiment occurred had a relatively larger projected image than what exists in most rooms. If this larger, more visible visual evidence significantly affected the results, the design of visual evidence appears to play a larger role in the comprehension of complex concepts than previously assumed.

Because the visual evidence for the topic-subtopic slides came from an assertion-evidence approach, the question arises whether presenters creating the slides using a topic-subtopic approach would create visual evidence of this quality. Therefore, a recommendation of this work is as follows:

Recommendation 1: Tests should be done to determine what visual evidence would be likely to arise from individuals following an assertion-evidence approach versus a topic-subtopic approach for the same topic.

Also tested in our experiment was the short-term and long-term retention of statistics and other factual information from the presentation. In the first experiment, the assertion-evidence group scored considerably higher on the recall tests. This result is even more exaggerated in the long-term retention test. This finding suggests that the assertion-evidence approach has a large impact on the long-term retention of complex technical concepts.

Conclusion 2: The assertion-evidence approach led to increased short- and long-term retention of complex technical concepts.

This conclusion was also reflected in the results of the second experiment. For more important facts that were included on both sets of slides (either as text or as visual evidence), the
assertion-evidence participants had a recall that was as good as, or in some cases distinctly better, than participants viewing the topic-subtopic slides for both experiments. That increase in recall can be attributed to those details being emphasized in the headline or in graphics on the assertion-evidence slides, as opposed to bulleted lists on the topic-subtopic slides. Not surprising, the topic-subtopic participants fared better with secondary details—details that the assertion-evidence approach did not consider important enough to place on the slides. However, as with comprehension, retention could have also been affected by the animated bullet points or the larger size of the projected image in the second experiment. This finding raises the question of whether the better recall of secondary information by the topic-subtopic group occurred at the expense of losing focus on the primary details.

Recommendation 2: When the presenter wants the audience to recall specific primary factual details, as opposed to secondary factual details in a presentation, the presenter would benefit from using an assertion-evidence approach.
Appendix A: Script for Slides

The following are the scripts for the presentations of both experiments. The numbers in brackets refer to the slide numbers that were projected while that text was narrated.

First Experiment

[1] Currently, the National Cancer Institute estimates that 1 in 2 people in the United States will develop a case of cancer in his or her lifetime. Think about all of the people in your life: your parents, grandparents, siblings, cousins, and friends. Chances are that several of these people will develop cancer. The American Cancer Society estimates that this year, more than 1.5 million new cases of cancer will be diagnosed and more than 500,000 people will die of the disease.

[2] The human body is made up of hundreds of different types of cells which, under normal conditions, divide in a controlled fashion. Occasionally, cells can become damaged by a mutation in the DNA. When a mutation happens, cells are programmed to die so that the mutated cells cannot divide and spread. In a cancerous state, however, the programming that directs a cell to die after a mutation occurs does not function properly. Mutated cells can then divide and spread uncontrollably. When this uncontrollable dividing and spreading happens in tissue, cancer has begun and a tumor grows.

[3] Because these cancer cells are different from the native tissue, they have different physical properties. One such altered property is the density of the tissue. The differences between the tumor tissue and the normal tissue are what allow the tumors to be detected.

[4] Magnetic resonance imaging, or MRI, has been one of the most recent developments in cancer detection. MRI can create a three-dimensional image of the tumor and the surrounding
healthy tissue so that healthy tissue is not removed during surgery. In addition, MRI can be used to highlight even the tiniest of cancerous tumors. Detecting tumors while small can greatly improve chances of successful treatment and survival rates.

[5] The two main technical components of an MRI machine are the superconducting magnets and the radio-frequency, or RF, transceiver. As the name “magnetic resonance imaging” implies, magnets are an important part of the function of an MRI machine. Within the MRI machine, three sets of superconducting magnets are positioned to produce a magnetic field in a particular x, y, or z plane through the patient’s body. The radio frequency transceiver in the machine is able to both transmit and receive radio frequency waves. The importance of this transceiver will soon become apparent.

[6] If you recall from your general chemistry classes, all atoms have a certain “spin.” This spin is essentially an axis through the atom that acts like a vector. At any given moment, the spins of the atoms within your body point in random directions. The superconducting magnets inside the MRI machine function to apply a magnetic field to the body that causes the spins of the atoms in your body to become aligned parallel to the magnetic field.

[7] Once the atoms are aligned with the magnetic field, pulses of radio frequency waves are applied to the body at a frequency that specifically targets hydrogen atoms. Hydrogen atoms are targeted because hydrogen is so plentiful in the human body. For instance, the body is more than 55% water, and each molecule of water has two hydrogen atoms. When these radio frequency pulses pass through the body, some of the hydrogen atoms absorb the wave’s energy and are able to overpower the magnetic field. The spins of these hydrogen atoms will no longer be aligned with the magnetic field because the atoms are in a higher energy state.

[8] When the pulses of RF waves are turned off, the magnetic field takes over again and forces the atoms that had absorbed the radio frequency energy to realign parallel to the magnetic field. In doing so, the atoms are returning to a lower energy state and must release some energy.
That energy is emitted as a radio frequency wave which can be detected by the RF transceiver. The exact frequency of the emitted signal is tissue-dependent. This dependency means that signals emitted from dense tissue such as bone and cartilage will have frequencies different from signals from less dense tissue such as fat and internal organs. Hydrogen atoms in cancerous tumors would emit a signal with a slightly different frequency from all of these.

[9] The radio frequency signals emitted from the body must then be converted into an image. To perform this conversion, the transceiver detects the radio frequency signals, which are then processed using a special mathematical transformation, called a Fourier transform. This transform helps convert the mathematical signals into an image. The resultant MRI image is extremely detailed.

[10] By repeating the MRI process at different locations, successive images from different “slices” of the body can be compiled to create a three-dimensional image that essentially maps out the body. The use of magnetic resonance imaging for the early detection of cancer results in clear, sharp images that can show tiny tumors in tissue in three-dimensions.

[11] The detections of these tiny tumors by MRI often occur before they can be felt by the patient or physician. While many factors help to predict the prognosis and survival rate of cancer patients, tumor size is a very important indicator of survival. In 2007, a breast cancer study of 10,000 Australian women showed that 5-year survival rates increased as the size of the discovered tumor decreased. When the discovered tumor was less than 10 mm in diameter, the individual had a 98% chance to survive at least five years. This survival rate decreased as discovered tumor size increased, and individuals with discovered tumors greater than 30 mm in diameter had only a 73% chance to survive for five years. For that reason, the use of magnetic resonance has the potential to prevent many of the more than 500,000 deaths caused by cancer in the United States each year.
Second Experiment

[1] Currently, the National Cancer Institute estimates that 1 in 2 people in the United States will develop a case of cancer in his or her lifetime. Think about all of the people in your life: your parents, siblings, relatives, and friends. Most likely, several of these people will develop this disease. For instance, chances are that 1 in 6 men will develop prostate cancer, and 1 in 8 women will develop breast cancer.

[2] The American Cancer Society estimates that each year, more than 550,000 people in the United States will die of cancer. Think about that number. Given that Beaver Stadium holds almost 110,000 people, the number of people who will die this year from cancer would be enough to fill Beaver stadium five times.

Exactly what is cancer and how does it occur? [3] The human body is made up of hundreds of different types of cells which, under normal conditions, divide in a controlled fashion. Occasionally, cells can become damaged by a mutation in the DNA. When a mutation happens, cells are programmed to die so that the mutated cells cannot divide and spread.

[4] In a cancerous state, however, the programming that directs a cell to die after a mutation occurs does not function properly. Mutated cells can then divide and spread uncontrollably. When this uncontrollable dividing and spreading happens in tissue, cancer has begun and a tumor grows. Cancer cells do have a chemical make-up and density that is different from other cells. These differences are what allow the cancerous tissue in tumors to be detected.

[5] One way to reduce the number of deaths resulting from cancer is to detect cancer in its early stages, when the tumors are small. While many factors help to predict the prognosis and survival rate of cancer patients, tumor size is an important indicator of survival. In 2007, a breast cancer study of 10,000 Australian women showed that 5-year survival rates increased as the size of the discovered tumor decreased. When the discovered tumor was greater than 30 mm in
diameter, the individual had only a 73% chance to survive at least five years. However, this survival rate increased as discovered tumor size decreased, and individuals with discovered tumors less than 10 mm in diameter had a 98% chance to survive for five years.

A tumor that is less than 10 mm in diameter is small—in fact, if deep below the skin, too small to be felt by a patient or physician. [6] To detect such a tumor, physicians have to use special detection equipment. Magnetic resonance imaging, or MRI, has been one of the most recent and important developments in cancer detection. MRI can be used to highlight even tiny cancerous tumors. In addition, MRI can create a three-dimensional image of the tumor and the surrounding healthy tissue so that healthy tissue does not have to be removed during surgery.

This talk discusses how an MRI can be used to detect cancer at its early stages. Because engineers play an important role in the continuing improvements of magnetic resonance imaging, it is important that engineers understand how this process works.

[7] An MRI machine has three main technical components. The first is a large superconducting magnet that is turned on before the scanning process begins and remains on for the entire scanning process. As the name “magnetic resonance imaging” implies, magnets play an important part in an MRI machine. The purpose of the large superconducting magnet is to produce a magnetic field along the patient’s body. This magnetic field, on the order of 1.5 Teslas, is extremely strong. For instance, such magnets have moved vehicles parked too close to an unshielded MRI building. Because of this field strength, patients are not allowed to hold or wear any ferromagnetic material when they enter the room with the machine. Moreover, people with pacemakers and metal implants are not even allowed to have an MRI scan.

The second main component of an MRI machine is an array of three gradient magnets that turn on and off many times during the scanning process. Essentially, these gradient magnets work to create a magnetic field in a small volume of the patient’s body. This gradient magnetic field counteracts the superconducting magnet’s field just enough in this small volume that the
resonance part of the MRI process can occur. This small volume is cube-shaped, with sides as small as 2.5 mm.

The third main component of an MRI machine is the radio frequency transceiver, which can both transmit and receive radio frequency waves during a scan. The purpose of these radio frequency waves will soon become apparent.

[8] If you recall from your general chemistry classes, all atoms have a certain “spin.” This spin is essentially an axis through the atom that acts like a vector. At any given moment, the spins of the atoms within your body point in random directions. For a patient placed in the MRI machine, though, the magnetic field from the large superconducting magnet causes the spins of the atoms to become aligned parallel to the field’s direction.

At the beginning of a scan, the gradient magnets turn on, producing a countering field in one small cube or voxel of the patient’s body.

With the magnetic field in this voxel now significantly lower than the field in the rest of the body, [9] the transceiver sends a pulse of radio frequency waves that targets a specific type of atom: hydrogen. One reason that hydrogen atoms are targeted is that hydrogen is so abundant in the human body. For instance, the human body is more than 55% water, and each molecule of water has two hydrogen atoms. When the radio frequency pulse passes through the voxel with the reduced magnetic field, some of the hydrogen atoms in that voxel absorb enough energy that they are able to overpower the magnetic field. In other words, the spins of these atoms are no longer aligned with the magnetic field because the atoms have moved to a higher energy state.

[10] When the gradient magnets turn off, the field of the superconducting magnet takes over again and forces those atoms that had absorbed the radio frequency energy to realign parallel to the field. In doing so, the atoms return to lower energy states and must release some energy. That energy is emitted as radio frequency waves which can be detected by the RF transceiver. The exact frequency of each released RF wave depends on the type of molecule in which the
hydrogen atom resides. For instance, a hydrogen atom in a hemoglobin molecule containing oxygen releases a slightly different frequency than a hydrogen atom in a hemoglobin molecule without oxygen.

[11] From that voxel, the transceiver then receives a spectrum of radio waves. This spectrum of the emitted signals depends on the types and numbers of molecules in that voxel. For instance, the spectrum emitted from a voxel situated within bone would be different from the spectrum emitted from a voxel situated with an internal organ. A voxel within a cancerous tumor would emit a spectrum that is different from both of these.

[12] The radio frequency spectrum transmitted from the voxel and received by the transceiver must then be converted into an image. To perform this conversion, magnetic resonance imaging uses a special mathematical transformation, called a Fourier transform. This transform helps convert the mathematical signals into an image.

[13] After the resonance imaging process has occurred in one voxel, the gradient magnets turn on again, but now shift the counteracting magnetic field to a second voxel. The resonance imaging process then occurs in that second small volume. This detection process occurs from one voxel to the next across a slice of the patient’s body, until an image of that slice is formed.

[14] By repeating the MRI process across different scanning slices, successive slice images can be compiled to create a three-dimensional image that essentially maps out the portion of the body that is scanned. The use of magnetic resonance imaging for the early detection of cancer results in clear, sharp images that physicians can read to identify tiny tumors in tissue in three dimensions. For that reason, magnetic resonance imaging has the potential to help prevent many of the 550,000 deaths caused by cancer in the United States each year.
Appendix B: Essay Question

Beginning on the next page, write a coherent description for the process of how magnetic resonant imaging (MRI) produces a three-dimensional image of the inside of the human body. In doing so, identify the following:

1. the roles of the machine’s main components in the MRI process,
2. the ways that atoms in the human body are affected by the MRI machine, and
3. how the MRI machine uses those effects to create a three-dimensional image that distinguishes cancerous tissue from other types of tissues.

Feel free to use subheadings, listed steps, and illustrations. Be sure to write complete sentences for listed steps and to provide clear labels for illustrations. Keep your essay to no more than 2 pages (including illustrations).
Appendix C: Rubrics for Scoring the Essay Test

First Experiment

Maximum for all three combined: 15 points

Question 1.

A. Superconducting magnets (1) produce a magnetic field (1/2) in a particular x, y, z directions (1/2)
B. Radio-frequency (1/2) transceiver (1) transmits radio frequency waves to the body (1)
C. Radio-frequency transceiver receives or detects radio waves from atoms in the body (1)

Maximum: 5.5 points

Misconception: 0.5 per (only penalized one time per question)

Distractors:

Resonance-frequency transceiver

Transceiver measures resonance frequency waves that it emitted and that bounce back

Superconducting magnets create an image in three-dimensions

Question 2.

A. After the magnets are turned on, the spins of (0.5) atoms align with the magnetic field (0.5).
B. Then when the radio frequency transceiver emits energy, (0.5) a percentage (0.5) of the hydrogen atoms move to a higher energy state (0.5).
C. When the hydrogen atoms move to a higher energy state, the spins of these hydrogen atoms are knocked out of alignment with the magnetic field (0.5).
D. Hydrogen (0.5) is targeted by the radio waves because the body is mostly water (55% water (0.5)) and water is mostly hydrogen (0.5).

E. When the transceiver stops emitting radio waves (0.5), the hydrogen atoms return to the lower energy state (0.5) and release energy as a radio wave (0.5).

F. When the atoms return to the lower energy state, the spins of the hydrogen atoms become realigned with the magnetic field (0.5).

Maximum: 6

Misconception: 0.5 per (only penalized one time per question)

In several papers, some of these details will be found in part 1.

Question 3.

A. Learner identifies that specific frequency of the radio waves received by the MRI depends corresponds to the type of tissue or cell from which they originate (0.5).

B. Learner goes further to say that bone, organs, normal tissue, and cancer cells all emit different frequencies. (0.5)

C. Learner goes even further to say these differences in frequency arise from the different densities (of hydrogen) in these tissues or cells (0.5).

D. Learner states that the MRI machine takes the radio-frequency waves and uses a mathematical transformation (or Fourier Transform (0.5)) to create an image. (0.5)

E. Learner recognizes that each positioning of the magnets leads to a thin image or slice (0.5)

F. The MRI machine then repeats the process to create several slices, which can be compiled (or stacked) into a three-dimensional image. (0.5)

Maximum: 3.5 points
Notes: If learner speculates that bone is most dense, that is okay. If learner says slice is two-dimensional, that is okay.

Distractor: Three-dimensional image created because magnets can produce image in three-dimensional space
Second Experiment

Presented in Table C-1 is the rubric for scoring the essay question. The rubric consists of 12 steps with each step having different components as represented by the different colors. Also, some of the components were boldfaced to indicate more importance. The third and fourth columns allow for descriptions of misconceptions and the appropriate deduction for each.

Table C-1. Rubric for Scoring the Essay Question.

<table>
<thead>
<tr>
<th>Process Items</th>
<th>Max</th>
<th>Score</th>
<th>Misconceptions</th>
<th>Deduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Superconducting (or strong) magnet creates field in patient</td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Spins of atoms, normally random in alignment, align with field</td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Gradient magnets create opposing field in voxel</td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. RF transceiver emits radio waves targeting H atoms</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Some hydrogen atoms gain energy and fall out of alignment</td>
<td></td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Gradient magnets are turned off</td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Magnetic field realigns the atoms; atoms return to lower energy state and release rf wave</td>
<td></td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. From each molecule, RF transceiver detects rf wave, which is different for different molecules</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. From each voxel arises an rf spectrum, which is different for different tissue</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. MRI uses a mathematical formulation, called a Fourier Transform, to create an image</td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Process occurs in different voxels across slice of patient’s body</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Process is repeated to create additional slices that are compiled into a 3-D image or map</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Process</td>
<td></td>
<td>22.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multiple Choice Test: First Experiment

1. What is the approximate ratio of people in the United State who will develop cancer in their lifetime?
   a. 1 in 2
   b. 1 in 3
   c. 1 in 5
   d. 1 in 7
   e. 1 in 10

2. This year, about how many people in the United States are expected to develop cancer?
   a. 15,000
   b. 50,000
   c. 150,000
   d. 500,000
   e. 1,500,000
   f. 5,000,000

3. This year, about how many people in the United States are expected to die from cancer?
   a. 15,000
   b. 50,000
   c. 150,000
   d. 500,000
   e. 1,500,000
   f. 5,000,000

4. What normally happens after a mutation occurs in the DNA of a cell?
   a. The cell immediately divides
   b. The DNA continues to mutate for the life of the cell
   c. The cell replicates uncontrollably and grows into a cancerous tumor
   d. The cell dies
5. About what percentage of the human body is water?
   a. 55 percent
   b. 65 percent
   c. 75 percent
   d. 85 percent
   e. 95 percent

6. In the MRI process, why is the percentage of water in the human body important?
   a. Because water is a good conductor of electricity
   b. Because water does not significantly affect magnetic fields
   c. Because radio frequency waves pass easily through water
   d. Because each molecule of water contains two hydrogen atoms

7. In a Magnetic Resonance Imaging (MRI) machine, what is the role of the superconducting magnets?
   a. To make the spins of all atoms in the patient’s body align in one direction
   b. To make the spins of all atoms in the patient’s body become oriented in random directions
   c. To make the spins of some atoms, especially those in cancer cells, align in one direction
   d. To make the spins of some atoms, especially those in cancer cells, become oriented in random directions

8. In the MRI process, what occurs in the patient’s body when the transceiver emits radio frequency waves?
   a. The spins of some atoms align with the magnetic field
   b. The spins of some atoms fall out of alignment with the magnetic field
   c. The spins of some atoms, especially those in cancer cells, align with the magnetic field
   d. The spins of some atoms, especially those in cancer cells, fall out of alignment with the magnetic field

9. In the MRI process, what happens just before atoms in the patient’s body emit radio frequency waves?
   a. The magnetic field is turned on
   b. The magnetic field is turned off
   c. The transceiver begins sending radio frequency waves
   d. The transceiver stops sending radio frequency waves
10. How does an MRI create a three-dimensional image?
   a. The magnetic field changes orientations in the x, y, and z planes
   b. The radio frequency transceiver changes orientations in the x, y, and z planes
   c. The MRI machine uses a Fourier transform to project depth for a two-dimensional image or slice
   d. The MRI machine compiles different two-dimensional images or slices

11. In 2007, a breast cancer study of 10,000 Australian women showed that 5-year survival rates
   a. increased as the size of the detected tumor decreased
   b. increased as the size of the detected tumor increased
   c. increased even though the sizes of the detected tumors essentially remained the same
   d. essentially remained the same with changes in tumor size detected

12. In 2007, a breast cancer study of 10,000 Australian women showed that the patient had a 73% chance of 5-year survival if the size of the tumor first detected was
   a. less than 10 mm
   b. 11-15 mm
   c. 16-19 mm
   d. 20-29 mm
   e. 30 mm or greater
Fill-in-the-Blank Test for Short-Term: Second Experiment

Please fill in the blanks below using information that you saw in the research participation talk.

Currently, the National Cancer Institute estimates that 1 in ____(1)____ people in the United States will develop a case of cancer in his or her lifetime. In particular, 1 in ____(2)____ men will develop prostate cancer, and 1 in ____(3)____ women will develop breast cancer. In the United States this year, _____(4)____ people are expected to die of cancer.

In 2007, a breast cancer study of 10,000 Australian women showed that 5-year survival rates __________(5)____________ as the size of the discovered tumor __________(5)____________. When the discovered tumor was less than 10 mm in diameter, the individual had a ____(6)____% chance to survive at least five years, while individuals with discovered tumors greater than 30 mm in diameter had a ____(7)____% chance to survive for five years.

According to the script, the superconducting magnet of an MRI machine is typically ____(8)____ teslas. Also, according to the script, a vox is a cube with sides as small as ____(9)____ millimeters.

Finally, according to the script, the human body is more than ____(10)____% water.
Appendix E: Delayed Post-Tests

Fill-in-the-Blank Test: First Experiment

Please fill in the blanks below using information that you saw in the research participation talk.

**Introduction.** Currently, the National Cancer Institute estimates that 1 in \(_,1\)_ people in the United States will develop a case of cancer in his or her lifetime. Typically, when a mutation happens in a cell of the human body, the cell \(_,2\)_ In a cancerous state, however, the mutated cell \(_,3\)_.

**Body.** Magnetic resonance imaging, or MRI, is an effective method for detecting cancerous tumors. The two main technical components of an MRI machine are the superconducting magnets and the \(_,4\)_ transceiver. The main steps of the MRI process for producing a 3-dimensional image of a brain are as follows:

With the patient lying on a bed inside the machine, the machine’s operator orients the superconducting magnets in a particular x-y-z direction and turns on the magnets. The resulting field causes the \(_,5\)_ in the patient’s body to align in the field’s direction.

Once these are aligned, the \(_,6\)_ sends \(_,7\)_ waves at frequencies that specifically target \(_,8\)_ These waves cause \(_,9\)_ to fall out of alignment with the magnetic field.

Then the \(_,10\)_ (are/is) turned off, and the \(_,11\)_ realign with the magnetic field. In doing so, they emit \(_,12\)_ signals that the transceiver detects.

These signals are converted to an image using a mathematical transformation called a \(_,13\)_.

Conclusion. In 2007, a breast cancer study of 10,000 Australian women showed that 5-year survival rates as the size of the discovered tumor. When the discovered tumor was less than 10 mm in diameter, the individual had a % chance to survive at least five years, while individuals with discovered tumors greater than 30 mm in diameter had a % chance to survive for five years.

Fill-in-the-Blank Test: Second Experiment

Please fill in the blanks below using information that you learned in the research participation talk.

1. According to the National Cancer Institute, in the United States, 1 in women will develop breast cancer. In addition, 1 in men will develop prostate cancer. Moreover, 1 in people in the United States will develop a case of cancer in his or her lifetime. Finally, according to the American Cancer Association, in the United States this year, people are expected to die of cancer.

2. In 2007, a breast cancer study of 10,000 Australian women showed that when the discovered tumor was less than 10 mm in diameter, the individual had a % chance to survive at least five years, while individuals with discovered tumors greater than 30 mm in diameter had a % chance to survive for five years.

3. The superconducting magnet of an MRI machine is typically teslas.

4. According to the script, the human body is more than % water.
References


ACADEMIC VITA

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Education
B.S., Chemical Engineering, 2013, Pennsylvania State University, University Park, Pennsylvania
Minor, German, 2013, Pennsylvania State University, University Park, Pennsylvania

Honors and Awards
Undergraduate Scholarship, Deutsche Akademische Austauschdienst (German Academic Exchange Service), 2012
Schreyer Academic Excellence Scholarship, Schreyer Honors College, Pennsylvania State University, 2008 - 2012
Leonhard Engineering Honors Program Merit Scholarship, Leonhard Center for Engineering Excellence, Pennsylvania State University, 2008 – 2012
International Travel Grant, Leonhard Center for Engineering Excellence, Pennsylvania State University, Spring 2012 and Fall 2012
Schreyer Ambassador Travel Grant, Schreyer Honors College, Pennsylvania State University, Spring 2012 and Fall 2012
Lincoln Scholarship, Association for Iron and Steel Technology, 2011-2012
BP Award for Achievement Scholarship, BP, 2011
MASWE (Men’s Auxiliary of the SWE) Scholarship, Society of Women Engineers, 2011
Air Products and Chemicals Inc. Scholarship Award, Society of Women Engineers, Lehigh Valley Chapter, 2008
Lutron Electronics Scholarship, Lutron Electronics, 2008

**Association Memberships/Activities**

Omega Chi Epsilon National Chemical Engineering Honor Society

Delta Phi Alpha National German Honor Society

Penn State Engineering Ambassadors

Society of Women Engineers

American Institute of Chemical Engineers

Association for Iron and Steel Technology

The American Ceramic Society

The Materials Information Society

The Minerals, Metals, and Materials Society

**Professional Experience**

Technical Marketing Internship, June-August 2009

GE Transportation, Erie, PA

Furnace Metallurgy Internship, May-August 2010 and 2011

Nucor Steel, Blytheville, AR

Recompletions Production Internship, May-August 2012

BP Americas, Houston, TX

Drive Train Internship, September-December 2012

Suzlon Wind Energy Corporation, Hamburg, Germany
Professional Presentations

Assertion-Evidence Slides Appear to Lead to Better Comprehension and Recall of More Complex Concepts

American Society for Engineering Education Conference 2011
Vancouver, British Columbia, Canada

High-quality Visual Evidence on Presentation Slides May Offset the Negative Effects of Redundant Text and Phrase Headings

American Society for Engineering Education Conference 2012
San Antonio, Texas

Publications and Papers
