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Slide Structure Can Influence the Presenter's Understanding of the Presentation's Content*

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Many undergraduate engineering programs use presentations as a means of assessing students' learning and technical communication skills, but the task of identifying slide structures that foster the presenter's thinking about his or her topic has received little attention. In most cases, students create topic-subtopic structure slides that follow the default settings of programs such as Microsoft PowerPoint. Our study explored the premise that the structure of a slide can also influence the presenter's understanding of the content. We asked 120 undergraduate engineering students to create slides that could be used to teach other students how MRI scans work. Roughly half of the participants ($n = 59$) were tasked with creating assertion-evidence slides. In the other condition, 61 participants created slides using a structure of their choosing. More than 80 percent from this second group created topic-subtopic slides. Within 24 hours, we gave the participants an unannounced post-test of comprehension. Results revealed a statistically significant advantage ($p < 0.05$) for participants who created assertion-evidence slides. Two takeaways from our study are (1) that the assertion-evidence structure led to a statistically significant increase in the presenter's understanding of the content, and (2) that the instruction needed to teach the assertion-evidence approach to the student presenters was minimal.

Keywords: presentation slides; PowerPoint; assertion-evidence; communication

1. Introduction

Engineering educators have responded to the need for engineering undergraduates to have good communication skills by increasing opportunities for these students to develop their writing and speaking skills. Many engineering undergraduates are required to take at least one course in communications, and design courses increasingly require students to deliver a presentation as a way of communicating their technical knowledge [1–4]. A recent survey of 232 engineering programs at American higher education institutions found that 87% of capstone courses included opportunities for students to improve their technical communication skills [1]. Of these, 92% included at least one formal oral presentation to faculty and fellow students. Encouragingly, these statistics represent a 22% increase from an earlier study [5].

The emphasis on improving communication skills has occurred along with a shift towards active learning techniques in engineering education [1, 2, 6–9]. Project-based and team-based coursework have become more prevalent in design courses, resulting in a need for students to be evaluated in ways that reflect this more authentic approximation of the professional world. This need has driven engineering educators towards identifying strategies that increase a faculty member's ability to evaluate the outcomes of project-based work, including presentations, and towards research designed to reveal effective instructional tools and strategies for this purpose [9]. Behind such efforts lie two assumptions about the creation and delivery of presentations: (1) student presentations are an appropriate method of evaluating students' learning outcomes, and (2) students benefit from the process of creating and delivering presentations. These assumptions are understandable given that an important component of technical communication is the demonstration of skill in technical content and the organization of such content [10]. By requiring students to teach others about their projects and the findings, engineering faculty members are treating presentation creation and delivery as a means to evaluate both communication skills *and* topic knowledge.

Given this increased emphasis on student presentations, it is important to understand how the creation of those student presentations affects the learning of the presentation content by both the other students in the room and the student presenters themselves. While multimedia learning researchers have studied how the structure of a presentation slide affects the learning by students in the audience [11, 12], little is known about how the creation of a presentation affects the student presenters themselves, particularly with regard to their understanding of technical concepts and processes [13, 14]. This fact, coupled with the substan-

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tial variation in the ways that presentations are used in engineering courses, raises two important questions for engineering education researchers. First, do certain strategies of creating a presentation promote learning by the student presenter more than other strategies do? If so, those more effective strategies could significantly increase the students' learning in engineering courses such as capstone design. Second, if such strategies for increased learning exist, do these strategies also support the learning by the student audience when those presentations are delivered? If not, then those strategies that serve the presenter would not serve the overall learning in the course.

Our study marks a step towards addressing the first question. We seek to understand the interaction between the creation of a student presentation and the learning by the student of the presentation's content. Our study does so by way of a comparison between the student creation of slides that follow the typical way that presentation slides are structured and the student creation of slides that follow an alternative structure that benefits the learning of the content by the audience [12]. To frame the study, we first consider links between communication activities and learning processes. Here, we describe the theoretical basis for our hypothesis—namely, that the structure and content of the visual aids that students prepare can impact their comprehension of material. We then present the findings of an experiment in which two groups of undergraduate engineering students drafted presentation slides on a topic previously unknown to them, and were subsequently tested on their knowledge of the topic. One group created slides using a standard presentation slide structure, and the other group used a structure that has been previously linked with increased audience comprehension [12, 15, 16]. After describing the findings of the study, this paper revisits the challenge posed above to engineering educators and considers the implications of using presentations as a tool for promoting the acquisition of knowledge as well as assessing communication skills.

1.1 The case for integrating technical presentations with self-directed learning

In 2008, the National Academy of Engineering published *Educating the Engineer of 2020*, a document in which desired attributes for engineering graduates were identified. The list of attributes included not only proficiency in communicating with expert and lay audiences about topics relevant to engineering, but also the desire and skills to promote lifelong learning [17]. Being able to propel one's professional knowledge forward through a career requires, at a minimum, sophisticated comprehension strategies that can support the construction of enduring understandings. Situations to which such strategies may be applied include reading printed or online text and images, experiencing multi-media presentations, and running laboratory based tests or computer simulations.

Explicit development of learning-how-to-learn skills is lacking from descriptions of capstone design and other courses requiring project-based or design-based work, even though they are specifically identified as desirable attributes for the student to acquire [18, 19]. Whereas a great deal of progress seems to have been made in terms of the frequency with which students are required to practice their communication skills, strategies for improving self-directed learning skills are less visible in the engineering education literature [20]. This gap is particularly prevalent when it comes to linking the two skill sets. Stated simply, very little has been done to explore the promise of presentation design as a learning strategy in itself. Most studies have focused on the implementation of presentations in engineering courses, along with perceptions of what makes them more or less effective in terms of students' communication skills and preparation for the workplace [10, 21, 22].

It with this prospect in mind that we turn to research and theory grounded in educational psychology. We propose that a parallel exists between the process of creating presentation slides and the process of drawing and paraphrasing material during self-guided studying. We propose that the deliberate practice of these two areas—self-directed learning abilities and presentation related skills—might be fruitfully integrated under certain circumstances. Specifically, we propose that the act of creating presentation slides is itself an exercise in learning that can impact the presenter's comprehension of the content, because it prompts the presenter to select important information, organize it, and communicate it using their own words. Furthermore, we propose a condition under which this activity is advantageous, which is when the student uses the assertion-evidence slide structure. Before describing this structure in detail, we provide a brief theoretical rationale for its features and its use in learning while creating a presentation.

1.2 A theoretical rationale for the role of presentation slide creation in learning

Our theoretical framework draws a parallel between the process of slide creation and the process of generating purposeful notes while reading. Basic and applied research in educational psychology has shown clear differences in learning outcomes associated with particular strategies used by students while they learn from textbooks, manuals and other forms of informational text [23–26]. Two related aspects of psychological processes are of particular relevance. One focuses on the task of encountering new information and the ways in which the information is encoded, which is to say that it is sifted and then integrated with prior knowledge. The other aspect focuses on the strategies that learners can use to create an external representation of the information that supports further learning or can be used to convey ideas to others.

1.2.1 Encoding

When learners encounter new information for the purpose of learning, three encoding processes must take place [27, 28]. First, the learner must *select* the most important information, disregarding unimportant or distracting details. Second, the learner must *organize* the information, such that elements of a system or parts of a conceptual relationship are situated relative to one another. Third, the learner must *integrate* the information with what they already know, by drawing on prior knowledge and comparing how this knowledge has been augmented, challenged, or otherwise affected by the new information [12, 23, 28].

Students who use learning strategies that prompt them to actively engage in these three encoding processes are more likely to be able to draw on that information to support subsequence recall and reasoning. They are also more likely to be able to convey the information to others more accurately. It would therefore seem reasonable to expect that students who engage in these processes while planning a presentation should be at an advantage in their learning compared with those who do not.

1.2.2 Externalizing

Parallel to encoding processes are representation processes, which are a variety of ways that learners create external depictions of the information. These strategies are intimately connected with encoding. They result from encoding but also support it when used to study from during a learning episode. In the case of learning from informational texts, one strategy for creating a meaningful external representation is to extract key points and put the information in one's own words. This strategy can be carried out effectively through paraphrasing and summarizing, both of which call on the presenter to generate shorter statements to capture the essence of a larger corpus of information [29]. The act of interpreting and synthesizing the information relies upon being able to select important content and organize it. This selection and organization in turn increases the likelihood that the new information can be integrated with other ideas.

Given that encoding and externalizing processes are mutually supportive, we propose that students can benefit from engaging in tasks that promote each process in iterative cycles. Specifically, we propose that the act of creating a presentation can promote information selection, organization, and integration. The reasoning is that the student presenter must review a large amount of information and select important points to share with the audience. In order for the audience to understand the information, the student presenter is compelled to impose an organizational structure on to it, even if it is a simple outline. Finally, in order to remember how to convey the information, generate applications of the content, or answer questions, the student presenter must situate the information within his or her existing knowledge. An example of an activity that meets all of these objectives would be to create a short paraphrase statement—or assertion—for each presentation slide, in order to convey a sequence of important messages for the set of slides.

Effective external representations of complex processes or systems often take the form of an image, graphic, or data display. This representation may occur with or without the presence of verbal statements or labels. Experimental research has shown that students who incorporate image-based representations such as drawings or diagrams are more likely to be able to call upon that information to answer higher order thinking questions afterwards. This effect is particularly the case when task instructions require students to learn about the components of a system or a multi-step process as they create their drawing or graphic. For example, in a study by Van Meter, students' comprehension and problem solving capabilities for scientific information were significantly increased by inspecting scientific text and illustrations and then using these to draw an integrated representation of the meaning of the text. Labeling the drawing, and paying close attention to the relations among informational elements, further promoted a deep understanding of the relations between structure and function within the overall biomechanical system of a bird's wing [30].

Because presentation slides can contain images, it is conceivable that student presenters who include images may be improving their understanding of the content. However, not all images are equally helpful in promoting learning [31]. Degrees of image sophistication and helpfulness vary and range from decorative, which is essentially a spurious image that does not contribute to the viewer's understanding of the content, to explanatory, which is an image that augments text by showing the organization and relations among informational elements. Explanatory images are superior in terms of promoting learning outcomes [31].

We argue that these findings are relevant to the student presenter who incorporates images into their slides. Specifically, we propose that student presenters who add decorative or descriptive (partially redundant) images to their slides are not maximizing the processes of encoding and externalization. Alternatively, students who seek explanatory images that depict processes, sequences, and relationships may benefit because creating or locating these types of images requires selection of key elements, organization of the elements into a system or process, and integration of the elements such that the function of the system or process is made explicit.

1.2.3 Integrating verbal with non-verbal representations

Learners benefit more when information is presented in both verbal and non-verbal (pictorial) media than in either one alone [28, 32]. However, in the case of multi-media learning such as learning from presentation slides, this increased benefit is realized only when text and image(s) mutually augment one another. Therefore, we hypothesize that student presenters may improve their content knowledge if they create presentation slides that include (1) a sentence assertion or synthesis statement that summarizes the information as an important message for the audience, and (2) images that explain the assertion and that are labeled in an informative way. In the following section, we describe a presentation slide structure called the assertion—evidence structure, which requires the student presenter to do each of these things in order to create a slide (or scene) for a technical presentation.

1.3 Commonly used slide structure versus assertion-evidence slide structure

How to structure presentation slides has been the subject of much debate in the past decade. What distinguishes the different proposed structures are the placement and nature of the text, images, and animations [33–35]. Our focus is on a comparison between the most commonly used slide structure, which is greatly influenced by the topic-subtopic default settings of Microsoft PowerPoint, and one alternative structure, the assertion-evidence structure, which originated as a response to the need for effective communication in science and engineering [33].

1.3.1 Different slide structures

In most engineering presentations such as for a meeting, at a conference, or in a classroom, the accompanying slides follow a topic-subtopic structure. That is, each slide contains a short, phrase heading at the top of the slide. The heading is commonly one to three words—for instance, "Introduction" or "Computational Results." The body of this type of slide then contains a bulleted list of items that summarizes the key points of the presenter. Images may or may not accompany the bulleted list (for examples presented as "model slides" from a widely cited capstone design course, see Fig. 1).

By contrast, the assertion-evidence slide structure contains a sentence assertion that is left justified at the top of the slide. Instead of a bulleted list, the body of the slide is composed of visual evidence that supports and explains the assertion. This evidence can be diagrams, photographs, drawings, graphs, or maps. Sparing use of "call out" text is positioned adjacent to the image to label or otherwise call attention to key elements of the information (for examples from a popular speaking contest for engineering students, see Fig. 2).

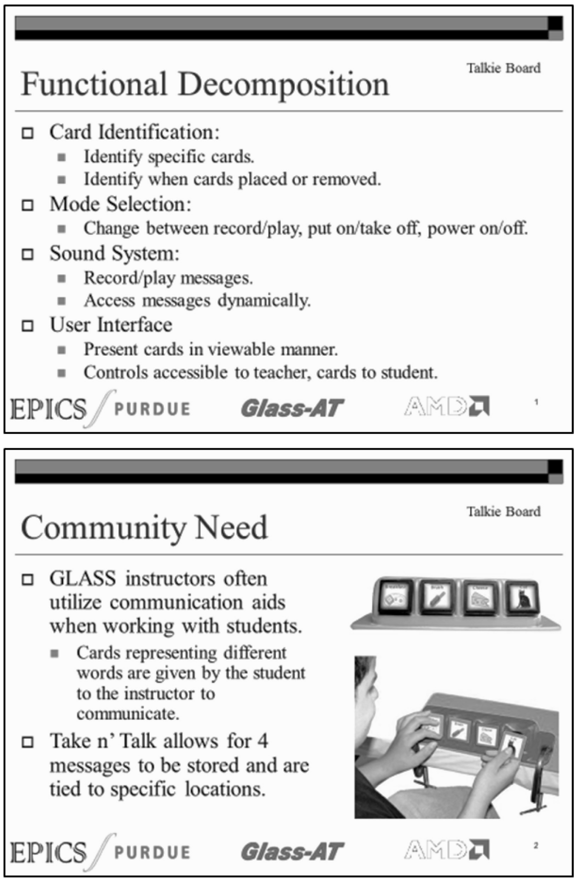

Fig. 1. Example topic-subtopic slides used as model slides in a widely cited capstone design course (EPICS/Purdue, 2015).

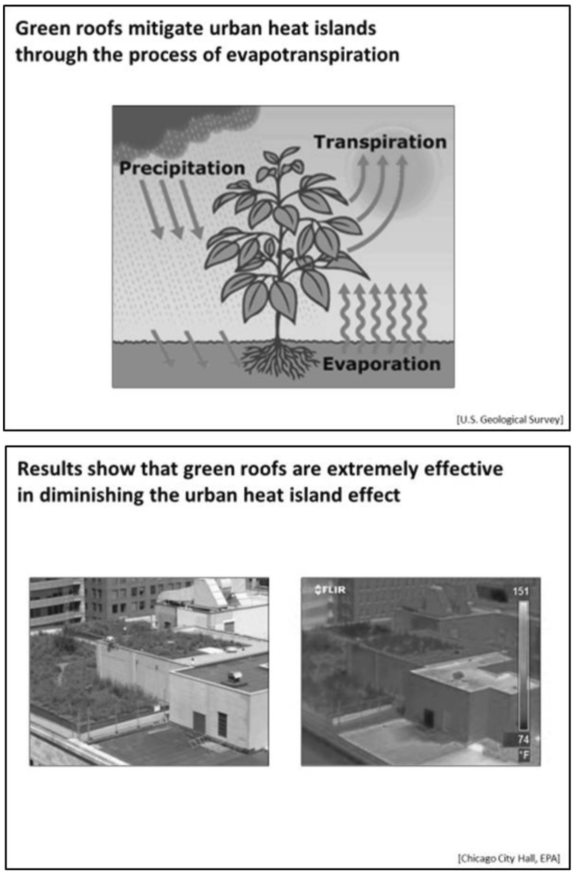

Fig. 2. Example assertion-evidence slides from a speaking contest for engineering undergraduates (Smith, 2013).

1.3.2 Implications for audience comprehension

The distinguishing characteristics of these two slide structures lead to differences in audience comprehension. For instance, Issa, Mayer, Schuller, Wang, Shapiro and Rosa conducted a study in which medical students received a lecture that was accompanied by presentation slides. In one condition, information was presented through text in the bulleted list format typical of the topic sub-topic structure.

In the other condition, slides were modified to include visual images with labels and, in some cases, a statement was placed at the top of the slide. At both one and four weeks after the lecture, students in the modified slide condition demonstrated superior recall of the information [16].

In a more controlled study, Garner and Alley examined college students' immediate and delayed recall of technical information about MRI machine structure and function. One group viewed an 8-minute narrated presentation that incorporated topic-subtopic elements such as phrase headings, bulleted lists, and bulleted lists accompanied by labeled diagrams. The other group heard the same narration but saw content presented using assertion-evidence slides that featured sentence headings and explanatory images. Text was used sparingly and primarily for labeling or for a short elaboration sentence. Similar to Issa et al., Garner and Alley found that students who viewed the assertion-evidence slides had superior comprehension and superior recall (both immediate and delayed) for the information when compared with students who viewed a presentation that was identical except for common topic-subtopic slides. Moreover, the assertion—evidence group had significantly fewer misconceptions than the topic-subtopic group [16].

We propose that these same characteristics found to influence audience comprehension *also encourage different ways of thinking about the information for the presenter as the presentation is created*. Specifically, we propose that compared with the topic-subtopic structure, the assertion-evidence structure is a more effective scaffold for student presenters as they encode and create externalized forms of the information. If this case holds true, then student presenters who use this structure should be at an advantage in terms of their understanding and recall of the information, compared with individuals who relied upon the topic-subtopic structure.

In the topic-subtopic slide, the phrase heading does not prompt the presenter to generate a paraphrased statement that connects the rest of the slide. In addition, the default bulleted list discourages the student presenter from capitalizing on the use of large explanatory images, and prompts the creation of an outline that does not articulate the connections or relations among information elements [16]. Because this structure spatially separates text from images, we propose that the student presenter does not have to consider the relationship between key points and how they might appear in concrete form. As a result, the student presenter is also discouraged from selecting or creating images that *explain* rather than simply depict the information.

The assertion-evidence slide structure, on the other hand, encourages the presenter to select key informational elements and paraphrase their meaning within the sentence heading. A visual representation of the relations among informational elements is prompted by dedicating the majority of the slide body to the visual evidence and its critical labels. Therefore, the student presenter must identify key ideas and articulate them as summaries or paraphrases of an idea, and then present the reason for the idea using images that are integrated with rather than separate from slide body text. In essence, the student presenter is scaffolded to *select* the main messages through paraphrasing, and then to *organize* and *integrate* the information via an assertion that is connected to visual evidence.

1.4 Our hypotheses

This study explored whether following a slide design, which is grounded in principles of audience learning, could conceivably impact the presenter's comprehension during the process of slide creation. Our two hypotheses were as follows:

1. Without intervention, students will tend to create topic-subtopic slides.
2. Students prompted to use the assertion-evidence slide structure will demonstrate increased learning over students who created topic-subtopic slides.

2. Methods

2.1 Participants and setting

Participating in the study were 120 undergraduate engineering students (n = 89 male, n = 31 female) who were enrolled in a presentations course at a large northeastern university. For the study, 59 students (n = 40 male, n = 19 female) were assigned to create assertion-evidence slides to communicate a technical process that was explained in a description. Likewise, 61 students (n = 49 male, n = 13 female) received the same presentation assignment, but were permitted to create slides in a structure of their choosing. The one constraint for the second "open" slide design group was that the slides had to have the same type of headline for all the slides. For instance, if the first headline was a phrase, all the headlines had to be phrases. The two groups of students performed the assignment on the same evening, but in separate rooms. The study occurred early in the semester before the course from which they were recruited covered the topic of slide design.

2.2 Procedure

In the study, both sets of participants received a packet with the same technical description for which they were to create presentation slides. Containing twelve paragraphs and two illustrations, the technical description explained the process of magnetic resonant imaging (MRI). As shown in Appendix A, the full technical description was organized into three distinct sections. The first section, which contained four paragraphs and one illustration, identified the main components of an MRI machine. The middle portion, which contained five paragraphs, explained the MRI process at the atomic and molecular levels. For this portion, the participants were to create five slides. The final portion, which contained three paragraphs, discussed how an MRI machine created images.

Before receiving the technical description, both sets of participants received instructions on what to create: slides for a presentation about magnetic resonance imaging. The beginning portion of the instructions was the same for both sets of participants:

> Forthcoming is a script for a classroom presentation on how magnetic resonance imaging works to detect cancer in the human body. Because undergraduate engineers are the primary audience, you are asked to draft the slides.
>
> 1. First read the script all the way through, focusing on the following:
>   a. The roles of the three main components of an MRI.
>   b. What occurs at the molecular and atomic levels in the human body during a scan.
>   c. How the MRI is able to tell what type of tissue is at each location.
> 2. Then, for the portion of the script *between the dotted lines*, create 5 slides that will be projected during the presentation.

What differentiated the assignment of the open-structure group from the assignment of the assertion-evidence group was the second half of the instructions. The participants of the open-structure group received the following instructions:

1. Then, for the portion of the script *between the dotted lines*, create 5 slides that will be projected during the presentation. Design the slides in the way that *you* think would provide the most effective projection. Given below is a common structure.
2. The body of the slide can change depending on the content: bulleted list, graphic, or bulleted list and graphic. However, be consistent in the way that you create the *headlines*. In other words, if your first headline is a phrase, make all the headlines phrases.
3. In designing the slides, remember that *all of the words in the script will be spoken during the presentation*. For that reason, use the slides to emphasize important details in the process.
4. For your visual evidence, sketch the graphic or image as best you can, but do not take too much time. Rough sketches are fine. If animation of images occurs, use numbered boxes to indicate order, as in the example below.

At the end of these instructions was an example slide, which is shown in Fig. 3.

As shown below, the participants in the assertion-evidence group received a slightly modified version of the instructions:

1. Then, for the portion of the script *between the dotted lines*, create 5 slides that will be projected during the presentation. Design the slides such

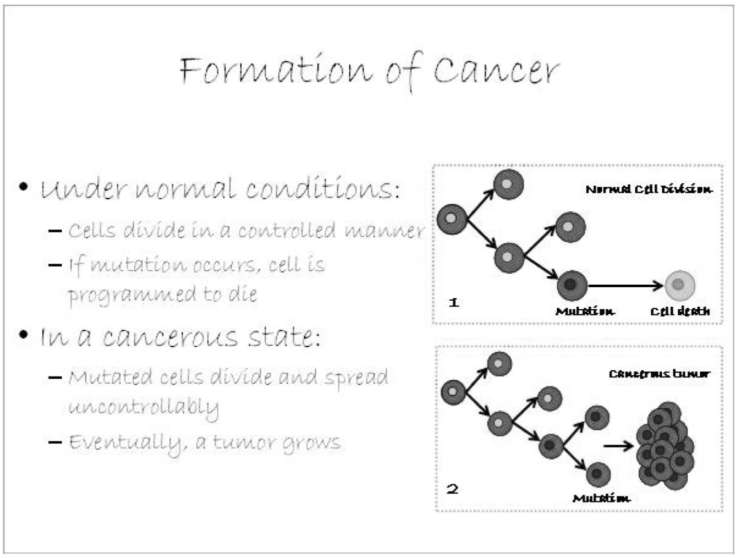

Fig. 3. Example slide for the open structure group. The numbers indicate order of animated images.

that the headline is a succinct sentence that states the main message of the slide. Given below is an example.

2. Also design the slides such that the body of the slide is visual evidence that supports the sentence headline: photos, drawings, diagrams, graphs. Labels for the graphics are fine, but please do *not* create bulleted lists. See the example below.
3. In designing the slides, remember that *all of the words in the script will be spoken during the presentation*. For that reason, use the slides to emphasize important details in the process.
4. For your visual evidence, sketch the graphic or image as best you can, but do not take too much time. Rough sketches are fine. If animation of images occurs, use numbered boxes to indicate order, as in the example below.

At the end of these instructions was an example assertion-evidence slide, which is shown in Fig. 4.

After a proctor read the instructions to the participants and each participant received the technical description, the participants had 60 minutes to create the five slides requested. At the end of the 60 minutes, each participant turned in the instructions, the technical description, and the five slides that he or she had created. Participants also completed a short survey about their prior knowledge of the process of magnetic resonance imaging. The

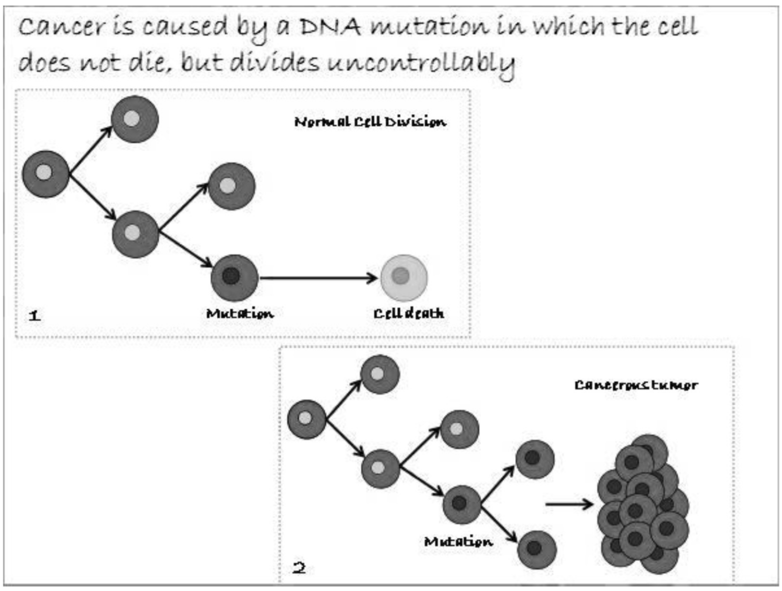

Fig. 4. Example slide for the assertion-evidence group. The numbers indicate order of animated images.

survey followed a 7-point Likert scale with 1 indicating no knowledge and 7 indicating much knowledge about the process. Both groups had statistically similar scores for their self-assessment of prior knowledge. The mean self-rating of prior knowledge for students in the assertion-evidence condition was 2.34 (SD = 1.39), and 2.71 (SD = 1.54) for students in the open condition. Controlling for prior knowledge ratings was therefore not necessary in order to enhance subsequent analyses.

Within 24 hours of creating the slides, the students received an unannounced quiz in their respective course sections. This quiz consisted of three essay questions, shown below, about how magnetic resonance imaging works. The first question was a control question based on what the participants read, while the next two questions probed to determine how much the participants learned from the portion for which they created slides:

Control: What are the roles of the three components of the MRI machine?

Probe (part 1): In the MRI process, what occurs at the atomic and molecular level within the human body? In your answer, use numbered steps, but do not hesitate to provide images and additional sentences to explain each step.

Probe (part 2): How is a MRI machine able to tell what type of tissue (tumor versus bone, for instance) is being scanned and how does the MRI machine know the location of this tissue?

The control question asked the students about information for which neither group created slides. In other words, the answer to the control question occurred in the four paragraphs before the dotted lines. In contrast, the probe items tested the students on the understanding of the material for which they created slides.

2.3 Data analysis

For the submitted slides from the open-structure group, we examined each set of slides to determine what slide structure the student created. These structures we classified as assertion-evidence, topic-subtopic, or hybrid. For the student submissions of unannounced quiz, two raters scored the essay questions, but did not know from which group the essay answers arose. The matrix for scoring the questions appears in Appendix B. Raters also recorded misconceptions that existed in the essay answers.

3. Results

3.1 Participants' slide structures

The slide structures created by the participants revealed two interesting findings. First, in accordance with the first hypothesis of our study, most students in the open section created slide designs that followed the topic-subtopic structure of PowerPoint. Second, even though the instructions for the assertion-evidence were minimal (only three instructional sentences and one example), most of the students receiving instructions for assertion-evidence structure were able to create slides that followed the structure. That finding is notable because if the assertion-evidence structure warrants adoption, this finding suggests that most people will be able to do so.

Table 1 shows the breakdown of slide structures for the two conditions. For the open condition, in which the student could select any slide structure as long as he or she was consistent, 50 of the 61 students created topic-subtopic slides. Here, topic-subtopic means that that the headline was either a phrase or short question. This headline then was supported either by a bulleted list, a bulleted list and a graphic, or by a graphic alone. As stated, this finding supported our hypothesis that most students would select the topic-subtopic slide structure, which PowerPoint's defaults have made ubiquitous. In addition, 7 of the 61 students chose a hybrid structure, in which one or more of the headlines were a sentence and one or more was a phrase or question. Because this choice was neither of the two structures for our analysis (topic-subtopic or assertion-evidence), we did not use the test results of these participants. Finally, 4 of the 61 students in the open condition selected an assertion-evidence structure. Because the slides of these four students did follow the assertion-evidence slide structure, the test scores of these four students were grouped with the assertion-evidence participants.

Shown in Fig. 5 are two common examples of topic-subtopic slides from the slide sets in the open condition. Both of these example slides have phrase headlines. Of the 50 sets of topic-subtopic slides, 41 sets had phrase headlines, while only 9 sets had question headlines. In addition, the body of the top slide consists of a bulleted list and a graphic, and the body of the bottom slide consists solely of a bulleted lists. For the 50 sets of topic-subtopic slides, these two structures for the slide's body were the most common. Of the 250 slides created for these 50 sets of slides (each set had five slides),

Table 1. Slide structures created by students in the open and assertion-evidence conditions

	Open (n = 61)	**Assertion–evidence (n = 59)**	**Analysis Totals**
Topic-Subtopic	50	0	50
Hybrid	7	6	NA
Assertion-Evidence	4	53	57

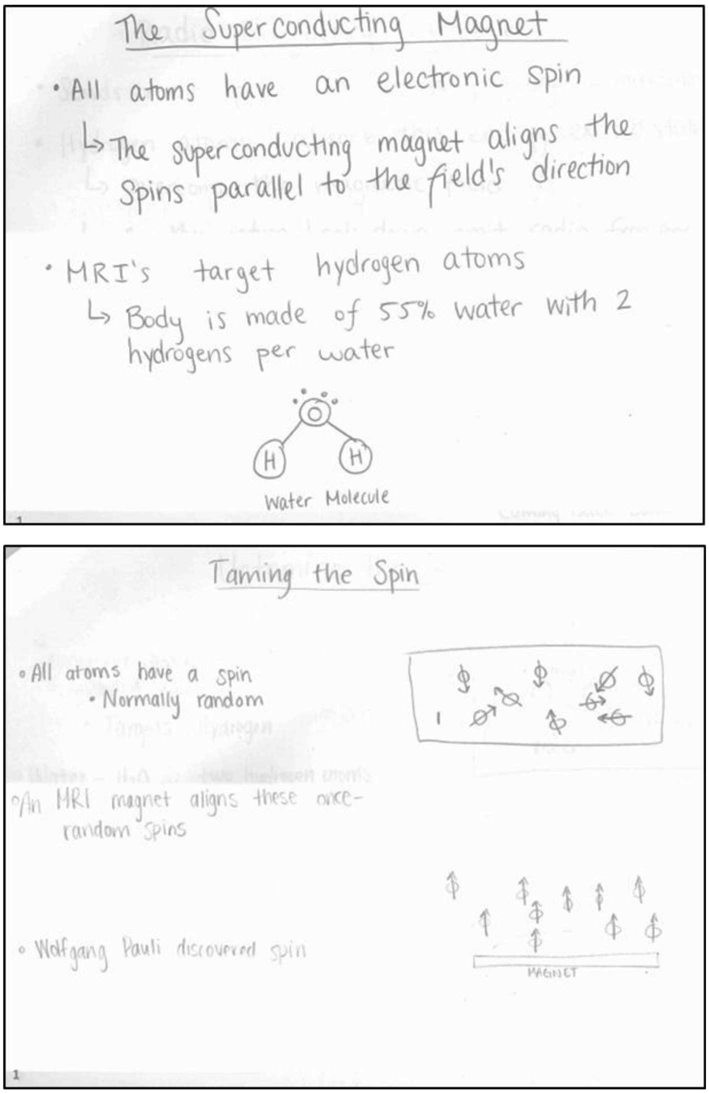

Fig. 5. Student slides that represent the topic-subtopic structure.

147 included both a bulleted listed and a graphic in the body, and 84 consisted solely of a bulleted lists. Out of the 250 slides, 19 had graphics only.

In both of these example slides, the largest and most prominent type on the slide was dedicated to identifying the topic. Moreover, in the top example, the student relegated the main takeaway of this scene as a second level bullet: "The superconducting magnet aligns the spins parallel to the field's direction." That the student has placed the most important detail into such a low position on the slide raises the question of whether the student understands the hierarchy of information for this portion of the process. In the bottom slide, the student essentially repeated all of the information from the paragraph into the bulleted list. This repetition raises the question of whether the student assigned a level of importance to the details of the process.

For the assertion-evidence condition, 53 of the 59 students created slides that followed the assertion-evidence structure of a sentence headline supported by visual evidence. Each of the 265 assertion-evidence slides created by the 53 students (5 slides per students) had a sentence headline. In addition, each of the 265 assertion-evidence slides had visual evidence supporting the headline. In none of the 265 assertion-evidence slides had students used a bulleted list. The remaining six slide sets in this condition were hybrid structures, in which one or more of the headlines were a sentence and one or more was a phrase or question. Because this choice was neither of the two structures for analysis (topic-subtopic or assertion-evidence), we did not use the test results of these participants. Adding the 53 assertion-evidence participants from this condition to the 4 assertion-evidence participants from the open condition gave us a total of 57 assertion-evidence participants, as shown in the third column of Table 1.

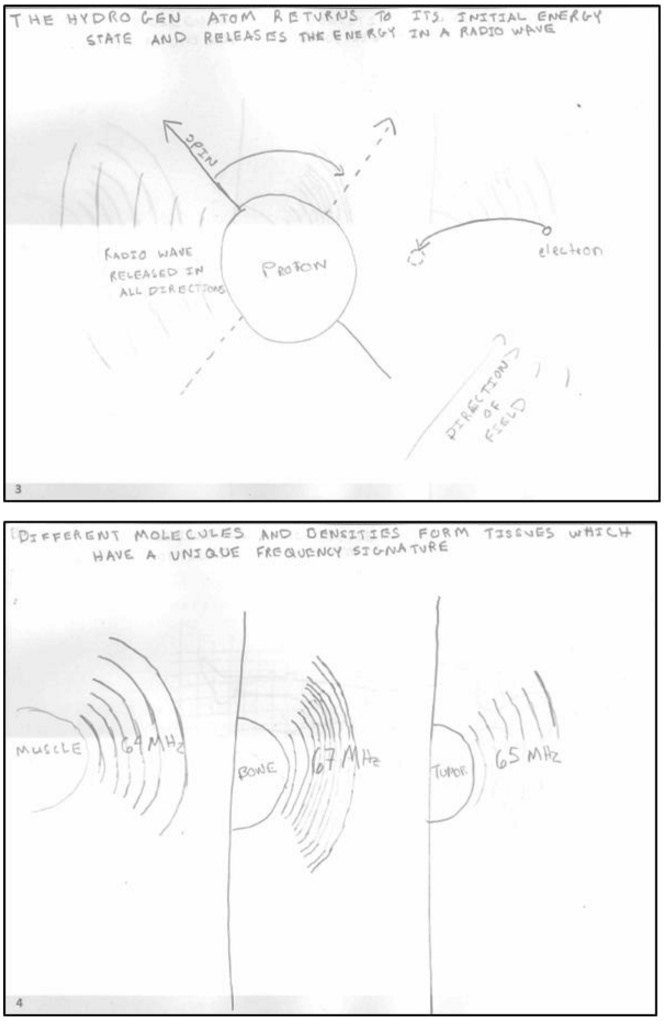

Fig. 6. Student slides that represent the assertion-evidence structure.

Shown in Fig. 6 are two example slides from the students who followed assertion-evidence structure. In both examples, the students synthesized the information in the respective paragraphs to come up with the main takeaway of each paragraph. In addition, both students used the space of the slide's body to construct graphics that supported the respective takeaway.

3.2 Posttest performance

3.2.1 Technical accuracy of extended responses

ANOVA was used to establish whether any group differences existed in regards to their *a priori* knowledge about magnetic resonance imaging, the total number of misconceptions detected in their descriptions, and to the total number of references to secondary information. When the data were aggregated across all questions, the two groups did not show any statistically significant differences on any of these measures. Posttest means and standard deviations for each group are presented in Table 2.

3.2.2 Accuracy of responses to questions of different cognitive levels

ANOVA analysis investigated whether the two groups differed in their score for technical accuracy for the three questions in the posttest. The control question served as a manipulation check; since neither group was asked to create a slide that included the information, any differences in cognitive processing because of the effect of slide structure should not yet be apparent. As expected, no significant differences were found for the control question. However, significant differences were found between the two groups for total scores on the probe items, $F(1,106) = 5.07$, $p < 0.05$. Scores were significantly higher for the students who created assertion-evidence slides. A moderate effect size of *Cohen's* $d = 0.49$ was calculated using the mean and standard deviation values. Descriptive statistics are shown in Table 3.

Together the results provide support for our prediction, which was that creating slides with an

Table 2. Descriptive statistics for posttest performance

	Open (n = 50)		**Assertion–evidence (n = 57)**	
	Mean	**SD**	**Mean**	**SD**
Total points	10.19	3.30	10.97	3.76
Misconceptions	1.1	1.11	1.09	0.95
Secondary information	0.27	0.37	0.12	0.26

Table 3. Posttest scores for each type of question

	Open (n = 50)		**Assertion–evidence (n = 57)**	
	Mean	**SD**	**Mean**	**SD**
Manipulation Check	4.51	1.45	4.51	1.55
Probe	5.91	1.88	6.93*	2.27

* $p < 0.05$.

assertion-evidence structure would benefit the presenter's understanding of the to-be-presented material, and that this benefit would be detectable through questions requiring higher order thinking about the topic area.

4. Discussion

Nearly all of the participants in each condition were able to complete the task as required. In the case of participants who were allowed to choose the type of slide structure that they created, more than eighty percent selected the common practice form of the topic-subtopic slide which consists of a phrase or question heading supported by a bulleted list, a bulleted list and a graphic, or a graphic alone. This finding provides support for our first hypothesis, which was that when given free choice to produce slides for a technical presentation, students turn to the topic-subtopic structure, which they are most likely very familiar with.

In the case of participants who were asked to create assertion-evidence slides, almost 90 percent were able to create slides that followed this structure. That such a high percentage of students could create slides using this structure was heartening because the instructions for doing so were minimal: three instructional sentences and a sample slide.

Analysis of the probing essay answers from the unannounced quiz showed that students who created assertion-evidence slides had a deeper understanding of the content than did students who created topic-subtopic slides. Given the random assignment to condition, the similarity of participants' ratings of their a priori content knowledge, and the similar scores for both groups on the control question, these scores on the probing essay answers support for our second hypothesis, and suggest that the slide structures can affect a student presenter's understanding of the presentation content.

Our findings represent a step towards understanding how the type of slides created might impact the learning processes of the presenter. Prior research on learning from presentation slides has focused on instructional design from the audience's perspective rather than from the perspective of the presenter. Similarly, prior research on paraphrasing, summarizing and drawing as strategies for self-directed learning have not typically focused on the creation of presentation slides. The need for integration between these two areas of research has clear relevance to engineering education, because an important goal is the ability of students to excel both in terms of professional communication skills and in terms of acquiring the self-directed learning skills. Because the assertion-evidence slide structure has been shown to benefit both learning the learning from the audience [16] and, in this study, the learning of individuals taking the role of student presenters, we suggest that slide structure can promote communication skills and learning skills at the same time.

Using the assertion-evidence slide structure also aided participants' ability to answer questions that required them to synthesize across the corpus of to-be-presented information, covering MRI machine structure, function, and common medical purpose. We suggest that the benefit may therefore lie in supporting higher order cognitive processes rather than the simple recall of facts or details. As such, our findings are parallel to studies that compared the effect of adopting learner-generated drawings as a strategy for learning about a system's information (Van Meter, 2001). However, unlike these studies, which were primarily conducted with K-12 students, the instructions used in our study were identical except for allowing students to generate their preferred slide structures in the common practice condition or stipulating that they use the assertion-evidence structure in the other condition.

Instructions were designed to elicit structural differences between two different types of learner-generated materials, and did not prompt participants to select or include particular elements of the information in their drawings. Our findings remain relevant to researchers who study student generated drawings. That is, our results support other studies that have shown how important it is to attend to the type of external representation that a learner creates, and how these representations may reflect differences in learner processes and outcomes [30].

Although speculative, we propose that creating a sentence assertion as a heading for each slide may have prompted participants to engage in beneficial paraphrasing activities that they would not otherwise have done. Moreover, the requirement that the sentence articulate an assertion may have encouraged students to extract causal or linking concepts within and between slides. As such, the sentence headline may have aided the students' construction of the connections across paragraphs of information, which is an important step towards improving comprehension of large chunks of information [36]. Similarly, it may be that the need to generate explanatory images to support each assertion may have prompted students to identify and consider the relations among particular aspects of the MRI machine and its processes in a manner that they otherwise would have otherwise overlooked. This suggestion is plausible, since participants in the assertion-evidence condition demonstrated an advantage on their knowledge of structure-function relationships.

Finally, it is promising that, like research on learner generated drawings, participants seemed able to follow the instructions and create assertion-evidence slides even though they had minimal training. This finding is important because if taxed by the constraints of the slide structure, the student presenter may find it difficult to comprehend the content that they are reviewing [37]. Clearly, further research is needed to understand the decision making processes that guide presentation slide creation. Such research would benefit the understanding by engineering educators of how to support the creation of presentation slides and the use of technical presentations as a pedagogical tool. Our study marks a small step towards the development of evidence-based recommendations for engineering students' technical presentations.

4.1 Limitations

Despite these promising results, there are several limitations to our findings. Perhaps the most significant one is that participants were tested immediately after they completed the task. Therefore, any long term effects of creating assertion-evidence or topic-subtopic slides cannot be determined from this experiment. However, prior work has revealed that the relative advantage of learning about a topic by viewing a pre-made assertion-evidence presentation is maintained over at least a one-week period [16]. We remain cautiously optimistic about the potential impact that may originate from presentation creation, although additional studies are needed.

A second limitation concerns the ecological validity of our study. Our participants did not actually present the slides that they created. Therefore, it is possible that even though their comprehension was improved, their overall retention of information after drafting, rehearsing and giving the final presentation may be similar across groups. Once again, this area is worthy of study prior to generating recommendations for course instructors. Related is a third limitation, which is that in many engineering courses, students prepare presentations on topics of their own choosing, and the presentations span a much larger array of work than simply the explication of a system or process. Thus, another next step might be to compare students who exclusively use the assertion-evidence slide structure for interim and final project presentations to students who use topic-subtopic structures or a variation thereof.

Finally, we are aware that the fusion of presentations and team-based learning that is common throughout the courses in engineering degree programs often means that groups of students are tasked with designing and delivering presentations. Thus, our findings do not speak to the potential impact on group-created slides. This area of research on the preparation of multimedia learning materials and drawings as a strategy for learning from scientific text has largely been ignored. Given that peers have been shown to act as co-regulators for one another's learning and task execution strategies [38] we propose that further research might explore how pairs or groups of students go about creating presentations, and whether slide structure impacts interpersonal interaction and the quality of all group members' learning outcomes.

5. Conclusion

In contemporary degree programs, engineering students often take courses in which they are required to make presentations of a technical nature. Prior research has investigated the degree to which project-based learning and team-based learning impact students' readiness for the workplace, but has largely ignored the prospect that the task of preparing the presentation may itself be a factor that influences the students' learning of the presentation topic. In this study, we revealed that creating presentation slides that conform to multimedia principles of learning, as opposed to slides that violate these principles, led to improved comprehension of the presentation topic. The unique contribution of the study is that although multimedia learning principles and the use of the assertion-evidence slide structure have been investigated in terms of audience comprehension, their impact on the presenter has to this date not been explored.

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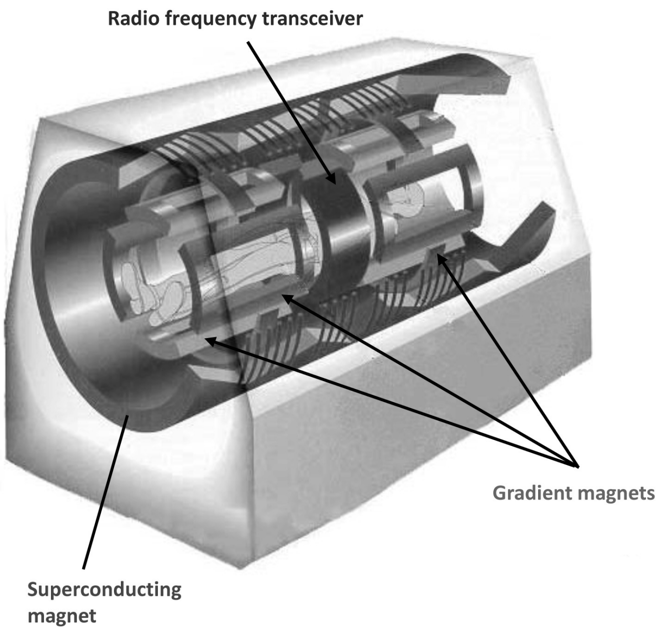
Appendix A: Technical Description That the Participants Received

How Magnetic Resonance Imaging Detects Cancer in the Human Body

A magnetic resonance imaging (or 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. The second main component of an MRI machine is the radio frequency transceiver, which can both transmit and receive radio frequency waves during a scan. The third main component of an MRI machine is an array of three gradient magnets that turn on and off many times during the 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 is extremely strong: on the order of 1.5 Teslas, which is enough to move a car. Because of this strength, patients are not allowed to wear any ferromagnetic material when they enter the room with the machine.



The purpose of the radio frequency transceiver is two-fold. First, it transmits radio frequency waves to the body at a specific frequency. Second it receives radio frequency waves from the body to create an image.

Essentially, the gradient magnets serve to determine the location of radio-frequency waves emanating from the body. The magnets do so by creating a magnetic field in a small volume of the patient's body. This volume, which is called a "voxel," is cube-shaped, with sides as small as 2.5 mm. Although the gradient magnet's field is much smaller than the field of the superconducting magnet (1000 times smaller), it is just large enough to alter the signals from that voxel.

Slides ↓

So how does the magnetic resonance process work to detect cancer in the human body? If you recall from your general chemistry classes, all atoms have a certain "spin." This spin, which is specifically the spin of the protons within the atom, creates an axis through the atom that acts like a vector. Normally, the spins of the atoms within your body point in random directions. However, for a patient placed in the MRI machine, the magnetic field from the large superconducting magnet causes the spins of those atoms to become aligned parallel to the field's direction. Wolfgang Pauli (of the Pauli Exclusion Principle) first identified this spin.

With the patient positioned in the superconducting magnets field, the transceiver begins sending pulses of radio frequency waves. Typically, the transceiver sends a pulse every 10 microseconds. The transceiver's pulses target a specific type of atom: hydrogen. One reason that hydrogen atoms are targeted is their abundance in the human body. For instance, the human body is more than 55% water, and each molecule of water has two hydrogen atoms. When a radio frequency pulse passes through the body, some of the hydrogen atoms 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.

During the short time span between each pulse, the excited hydrogen atoms relax back to their original energy state and become realigned with the superconducting magnets field. In doing so, the atoms return to lower energy states and must release energy. That energy is emitted as radio frequency waves which the radio transceiver can detect. The exact frequency of each released radio frequency wave depends on the type of molecule containing the hydrogen. For instance, a hydrogen atom in a hemoglobin molecule containing oxygen releases a frequency that is slightly different from the frequency of a hydrogen atom in a hemoglobin molecule without oxygen. As you might recall, hemoglobin is important because it carries oxygen from the lungs to the rest of the body.

The transceiver receives many such radio frequency waves from the body. Typically, the most common frequency emitted is about 64 MHz. All these radio frequency waves combine to form a spectrum for each type of tissue. The shape of the spectrum depends on the types and numbers of emitting molecules in that tissue. For instance, the spectrum emitted from bone would be different from the spectrum emitted from an internal organ. A cancerous tumor would emit a spectrum that is different from both of these. Interestingly, an additional 7-minute step in the MRI process can distinguish a malignant tumor from a benign tumor.

So how does the MRI exactly know where in the body the different radio frequency waves come from? Here is where the gradient magnets come in. As mentioned, when the gradient magnets turn on, they produce a field in one small cube, or voxel, of the patient's body. In effect, the magnetic field in this voxel is slightly, but distinctly, lower than the field in the rest of the body. For that reason, the relaxation time of the excited hydrogen atoms in the voxel is slightly longer than the relaxation times in the rest of the body. This difference in timing allows the radio frequency transceiver to distinguish the radio waves from the voxel and thereby identify the spectrum coming from that specific location of the body.

Slides ↑

After the resonance imaging process has occurred in one voxel, the gradient magnets turn on again, but now shift their 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 being scanned. Typically, the mapping of the voxels across a slice takes about 5 minutes. Because the image of the slice is not complete until all voxels in that slice have been scanned, the patient has to remain still. Otherwise, the image is blurred.

In scanning a slice, the gradient magnets rapidly turn on and turn off in each voxel across that slice. For those who have had an MRI scan, this rapid turning on and off by the gradient magnets is what causes the loud noises that accompany an MRI scan. In essence, the noises arise from electrical current expanding and contracting the gradient coils at a rapid rate. Once one slice is scanned, the MRI machine adjusts to begin scanning a second slice. These image slices can then be stacked to create a three-dimensional image for that particular part of the body.

The clarity and sharpness of MRI images allow physicians to identify cancerous tumors when they are small. Identifying such tumors when they are small (often less than 10 mm in diameter) is important, because that is when the cancer is in its early stages and can be treated more effectively.

Appendix B: Score Sheet for Evaluating the Essay Questions

Given below is the score sheet for evaluating the participants' answers to the essay questions. The second column contains content that needs to be conveyed to earn a score. The italics indicate that the answers had distinct parts. For instance, in 1A, an answer received only 0.5 points for stating that the superconducting magnets produced a magnetic field. To earn 1 point, the answer also had to convey that the magnetic field was "strong." The final column listed common misconceptions—other misconceptions did occur as well.

	Items	Pts	Misconceptions
1A	Superconducting magnets . . . produce a *strong* magnetic field	1.0	
1B	. . . that aligns *the spins* of all *the atoms (protons)*	1.5	hydrogen atoms only
1C	Radio frequency transceiver transmits *radiofrequency (rf)* waves *to body*	1.25	
1D	. . . receives *rf* waves *from body*	1.25	
1E	Gradient magnets provide a magnetic field	1.0	
1F	to small volume *called a voxel*	1.0	
	Subtotal for 1 (max = 7.0)		Subtotal Misconceptions:
2A	Normally the spins of atoms *point in random directions*	1.0	
2B	. . . atoms align with *superconducting magnetic field*	1.0	
2C	Transceiver sends pulses of RF waves that *target hydrogen atoms*	1.0	
2D	Some of these	0.5	. . . all hydrogen atoms
2E	. . . atoms move to a higher energy state	0.5	
2F	The spins of these atoms become unaligned *with the magnetic field*	1.0	
2G	After pulse ceases, *the hydrogen atoms* that gained energy *return to their original state*	1.5	When magnetic field turned off
2H	. . . realign with the main magnetic field,	0.5	
2I	. . . and release energy *in the form of a radio wave*	1.0	
	Subtotal for 2 (max = 8.0)		Subtotal Misconceptions:
3A	Each kind of hydrogen molecule emits a different frequency	0.5	
B	Each type of tissue consists of different types and numbers of molecules	0.5	
C	The spectrum of each tissue is unique	1.0	
D	The location is determined by the use of the gradient magnets	1.0	
E	Gradient magnets alter the field in the voxel (or in the small volume)	0.5	
F	. . .causing the timing of the release of energy from molecules within the voxel	0.75	
G	. . .to be delayed from the timing of the release of energy from rest of body	0.75	
	Subtotal for 3 (maximum = 5.0)		Subtotal Misconceptions:
	Total (maximum = 20)		Total