

AC 2009-1855: APPLICATION OF MULTIMEDIA THEORY TO POWERPOINT SLIDES CREATED BY ENGINEERING EDUCATORS

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Application of Multimedia Theory to PowerPoint Slides Created by Engineering Educators

Key Words: PowerPoint, multimedia learning, cognitive overload

Abstract

Each year, the ASEE annual conference hosts hundreds of presentations to help disseminate engineering education research to the more than 3,000 attendees. This paper examines the slides from 72 presentations at the 2008 ASEE Annual Conference and Exposition to determine common practices among engineering educators with regard to their presentation slides, and whether or not these slides followed accepted principles of multimedia design. These principles target the content and format of presentation slides and aim to increase the audience's comprehension and retention of information. Of the 72 presentations considered in this study, 31 received Best Paper nominations, 12 arose from the rigorous Educational Research and Methods Division, and 3 were plenary sessions.

In examining the 1,381 presentation slides from these 72 presentations, we determined common practices through a scoring rubric that considered the following three aspects of presentation slides: (1) slide structure (form of the headline and body); (2) slide density (the amount of text on each slide), and (3) frequency and classification of images (decorative, representative, organizational, and explanative).

In regard to structure, almost half of the slides per presentation had a topic phrase headline supported by a bullet-list. Almost one-fifth per presentation had a topic phrase headline supported by a bullet list and an image, and a similar percentage had a topic phrase headline supported by an image.

To capture slide density (the amount of text on the slide), we counted the number of lines of text and number of words. On average, engineering educators used 7.5 lines of text and 33.4 words to communicate their research. When broken down to words per minute viewed by the audience from presentation slides, these numbers correlate to about 35 words per minute, which is high. This finding raises the question whether cognitive overload for the audience typically occurs in these slide presentations. This finding also raises the question whether the slides of engineering educators violate multimedia principles of learning.

One of these multimedia principles concerns the frequency and classification (according to purpose) of images. This study shows that fewer than half of the slides per presentation contained an image. Using a scale used to rate the depth of purpose achieved by an images, we found the majority of images used were at the representative level, which means that those images identified but did not explain the topic of the slide. Also, almost half of the engineering educators used a decorative background. These backgrounds contain decorative images that multimedia researchers contend reduce the comprehension and retention of details.

The results of this study suggest that much room exists for engineering educators to improve the visual aids in their research presentations. However, before significant improvements will occur, presenters will have to challenge the defaults of PowerPoint.

Introduction

For the past decade, the overwhelming majority of presentations at the ASEE National Conference and Exposition have included visual aids in the form of computer-projected slides. To be most effective, these slides should help the audience better comprehend and retain the presentation's key information. Given that Microsoft PowerPoint controls 95% of the market for presentation slideware,¹ assessing the effectiveness of slides in technical presentations should begin with an examination of PowerPoint's default settings and the degree to which presenters are influenced by these defaults.

Figure 1 shows PowerPoint's default master slide for all slides but the title slide (in this paper, we will focus on slides following the title slide). This default master slide contains the program's key default settings. Except for changes in the choice of typeface, these settings have essentially remained the same since the program's creation in the mid-1980s by an entrepreneur, Robert Gaskins, and a computer scientist, Dennis Austin.² Although other master slides exist in PowerPoint, the common assumption is that the default master slide is where most presenters begin their slide designs, because selecting a secondary master slide requires the presenter to open a window (**View Slide Master**) that is normally hidden.

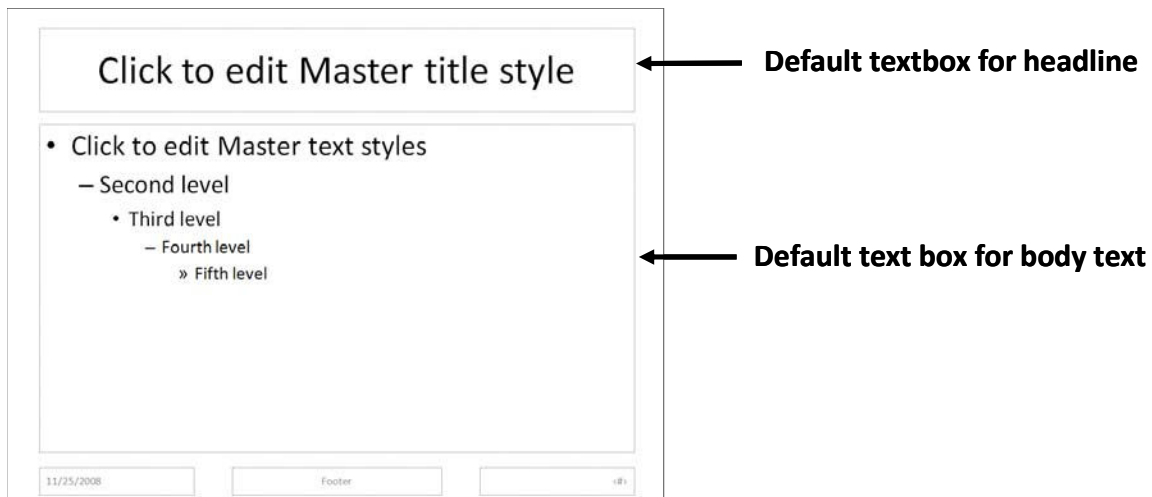


Figure 1: Default settings of PowerPoint's slide master.

One of the defaults on the default master slide is a centered headline in a large typeface (Calibri, 44 points)—this same default for the headline exists for 8 of the other 11 slide masters in PowerPoint. Because of the size and position of the text block, the common assumption is that this default leads presenters to create headlines that fit into the block—which would typically mean no more than six words. Because the headline is so short, the expectation is that the headline would more likely be a phrase, such as “Computational Results,” rather than a sentence: “Computational results show that the fillet eliminates the leading edge vortex.”³

A second default on the default master slide concerns the way text is incorporated into the slide's body—bullet lists are also called for on 6 of the other 11 slide masters in PowerPoint. This default, which originated during a time when images were difficult to incorporate into computer programs, calls for text to come in as a bulleted list that automatically fills a large text

box. Because of this default, the common assumption is that most slides contain such lists, that the number of words in these lists is significant, and that such lists reduce the space available for graphics.

Given this combination of defaults, the common assumption is that most slides would have a topic–subtopic structure. That is, the phrase headline would identify the main topic or idea of the slide, and the bulleted list beneath the headline would serve to identify multiple subordinate ideas related to the overall headline phrase. In the popular literature, this assumed structure has received strong criticism: *The New Yorker*¹; *Wired*⁴; *The New York Times*⁵; *The Chicago Tribune*⁶; *The Cognitive Style of PowerPoint*⁷; *The Wall Street Journal*²; and *The Sydney Morning Herald*.⁸

However, the defaults on the master slide might not necessarily correlate with what occurs in common practice, especially in this common practice among engineers. In this article, we examined 1381 slides from the 2008 ASEE National Conference and Exposition to identify a common practice for PowerPoint slides at this conference. Next in the article, we then apply principles of cognitive psychology to this common practice to assess how well such slides appear to help audiences comprehend and retain the content of the corresponding technical presentation.

Methods for Attaining Common Practice in PowerPoint Slide Design

Although the defaults of PowerPoint would appear to lead technical presenters to create a topic–subtopic structure for slides, the more important issue is what slide structure is actually used in common practice. In other words, how much do the default features of PowerPoint influence common practice in technical communication? Because so many millions of PowerPoint slides are created each day,⁹ finding a representative sample to characterize the common practice of slides across all technical presentations is difficult. Moreover, the contents and purposes of technical presentations vary such a great deal—from a technical manager’s presentation about a company’s annual activities to an engineer’s presentation about a specific technical project.

Despite this challenge, we have examined slides from one technical communication situation to determine the influence of PowerPoint’s defaults in that situation: research presentations created by engineering educators at the ASEE National Conference and Exposition. In selecting samples for this situation, we have aimed for a quality of slides that would be above average. The rationale here is that if these above-average slides do not follow cognitive psychology principles for communication, then the typical slides at this conference would not either.

For this situation, we considered 72 sets of PowerPoint slides that arose from the 2000 presentations given at the 2008 American Society of Engineering Education Conference. Of these 72 presentations, 31 received best paper nominations, 12 came from the rigorous Educational Research and Methods Division, and 3 were from plenary sessions. Again, an implicit assumption is that significant effort went into these slides, making them appropriate representatives of this technical communication situation.

To obtain these slides, we wrote to conference presenters from various categories and requested that they send us a copy of the slides that they projected so that we could collect “bulk statistics” about slide design. Because the slides had already been projected publicly, because the presenters had voluntarily sent us their slides, and because we were not redistributing any of these

slides, our Institutional Review Board deemed the slides to be in the public domain and therefore IRB approval was not necessary.

In our analysis of the slide structure, we limited ourselves to presentation slides in which the purpose was to communicate technical information for understanding and retention. Not considered were uses of presentation slides to identify the speakers or their institutions, to give acknowledgments or disclaimers, or to serve as placeholders in a presentation—such as a *Questions* slide at the end.

Appearing in Table 1 are the results of the survey for the structure of the slides. As hypothesized, the headline default of PowerPoint strongly influences the structure of the headline. For the slides examined at this conference, about 85% of slides per set have a phrase headline. This statistic is important because the headline frames the visual aid for both the presenter and the audience. A phrase headline serves to identify the topic of the slide—in general, the shorter the phrase, the less defined the topic.

Table 1. Common practice statistics on slide structure.

Feature	Statistics	
	Mean	S.D.
% of slides per set with phrase headline	85%	0.23
% of slides per set with bullet lists	71%	0.32
% of slides per set with phrase headline and bullet lists	65%	0.25
Number of slide sets	72	
Total number of slides	1381	

In addition, as assumed in the popular literature, the body-text default of PowerPoint strongly influences the structure of the slide’s body with more than 70% of slides per set in each situation having a bullet list. This statistic is important because bullet lists having too much text can lead to cognitive overload, which is discussed in the next section. In addition, from a communication perspective, bullet lists do not show connections between details,¹⁰ and such connections are important for audiences of technical presentations to process complex information.

In our survey, the combination of these two defaults led to 65% of the slides per set in each situation having a topic–subtopic structure, which correlates to a phrase headline being supported by a bullet list. About two-third of the slides with this topic–subtopic structure had no graphics. Shown in Figure 2 is a prototypical slide of this case. To protect the identity of conference attendees who submitted slides for this project, this prototype was drawn from public domain slides outside the conference. However, in terms of average number of words and lines, this slide is prototypical for topic–subtopic slides without graphics.

The other one-third of slides with the topic–subtopic structure had a graphic: photograph, drawing, diagram, graph, or table. Shown in Figure 3 is a prototypical example of this case. As stated before, this prototype arose from public domain slides rather than from a conference presenter’s set of slides. However, in terms of average number of words and lines, this slide is prototypical for topic–subtopic slides with graphics.

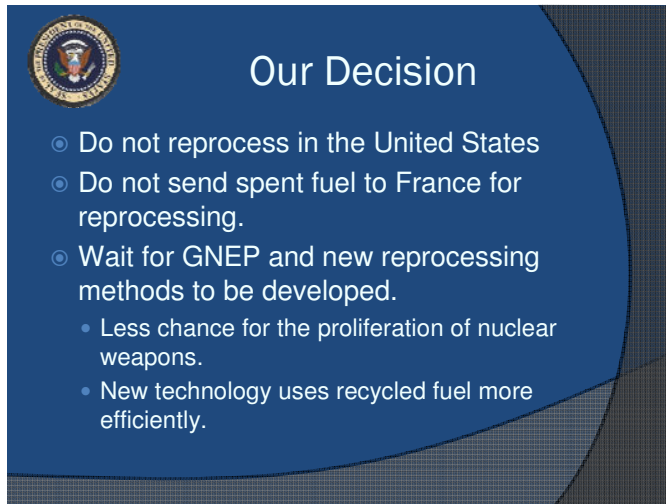


Figure 2. Prototypical slide for topic–subtopic structure with no graphic.

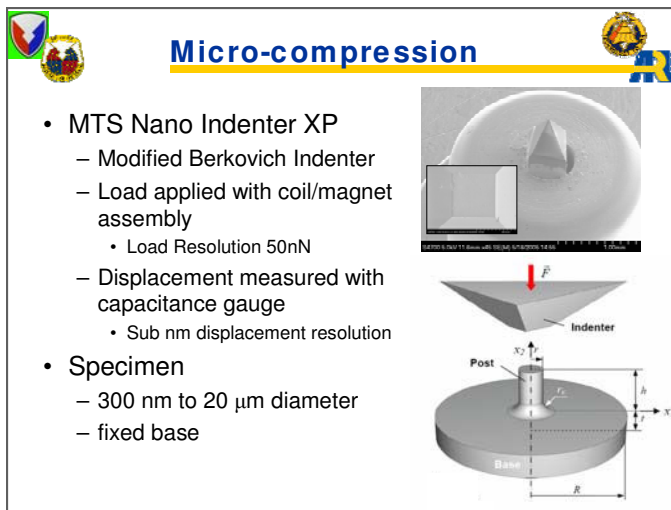


Figure 3. Prototypical slide for topic–subtopic structure with a graphic.

Overall, these results demonstrate the strong influence that PowerPoint’s defaults have on the slides created by technical communicators for the ASEE National Conference and Exposition. About two-thirds of slides per set contained the topic–subtopic structure of PowerPoint. Moreover, about two-thirds of these topic–subtopic slides did not have a graphic. Now we turn to the question of the effect that this influence of PowerPoint may have on the comprehension and retention of information by audiences. Although critics in the popular literature have criticized the topic–subtopic structure of PowerPoint, these critics have not methodically assessed whether this structure follows cognitive psychology principles for multimedia learning, as our paper will do.

Multimedia Principles Derived From Cognitive Psychology

A goal for the creator of a technical presentation is to design visual aids that support the audience's comprehension of his or her intended message. From a cognitive psychological perspective, achieving this goal means that the multimedia presentation must avoid imposing too much *cognitive load* on audience members. Cognitive load refers to the degree of effort, strategy, and processing capacity that an individual must exert to understand information. Two principles of cognitive psychology are important in assessing the cognitive load of a presentation slide: the Theory of Cognitive Load and Dual Code Theory.

According to the Theory of Cognitive Load,¹¹ information can be characterized on a continuum from low to high element interactivity. Low interactivity implies that individual concepts can be understood without the need to reference other information; high interactivity implies the opposite. In fact, highly interactive informational elements can only be partially understood if elements are not considered in relation to one another. Understanding highly interactive information, however, places a high cognitive load or demand on the audience member's short term working memory system—the limited capacity memory system that acts as a gateway to long term memory formation. For that reason, particular attention must be paid to the way in which information is presented so as to avoid increasing the difficulty level to the point where comprehension breaks down.

Sweller stipulates two types of cognitive load: intrinsic and extrinsic.¹² Each has separate causes. Intrinsic cognitive load is load that is inherent within the information being presented. Understanding highly interactive information, such as the how the parts of a complex system affect one another, places a high intrinsic cognitive load on the learner. Such a situation requires a great deal of working memory capacity to process incoming information and manipulate it so as to comprehend the relationships among its elements. To a degree, a presenter can control intrinsic load by making decisions about what information he or she will present. The presenter can also plan to explain concepts in more or less detail, and to highlight or gloss over relationships between concepts.

Extrinsic cognitive load arises primarily from the method by which information is presented. That is, extrinsic load can be influenced by how information is presented on a slide, including the amount and format of the information, rather than the actual conceptual meaning of the information on the slide. Depending on the way that a presenter's visual aids are structured, extrinsic load may be increased or decreased and may therefore impact audience members' comprehension in a negative or positive way.

Meanwhile, Dual Code Theory states that information is more easily learned when verbal and image-based formats are meaningfully integrated together rather than when one or the other format is used exclusively.^{13, 14} Put another way, every audience member has two pathways for understanding information: a verbal pathway, which processes words that might be heard or read; and a pathway for images. In a presentation, if the audience has to simultaneously listen to words spoken by the presenter and read many words on a projected slide, the verbal track can easily become overloaded. However, experiments have shown that this overload does not occur when those written words are replaced by images, which the audience processes through the image track. In fact, the integration of verbal and visual information can be beneficial for learning.

For that reason, helping individuals comprehend high intrinsic load information, while taking efforts to eliminate extraneous extrinsic cognitive load, results in superior quality comprehension, retention, and transfer of information after learning has taken place.¹² Therefore, logical questions for those interested in the effectiveness of presentation slides are *how do common practice slides increase or decrease audience comprehension*, and *how can presentation slides optimize intrinsic load while minimizing extrinsic load?* Answers and solutions could more effectively allow presenters to reach their communication goals.

Comprehension and Retention of Common Practice Slides

Research in multimedia learning has generated a number of principles of instructional design that are congruent with the Dual Code and Cognitive Load perspectives. According to Mayer,^{15, 16} learning from multimedia presentations—including PowerPoint presentations—is optimized when certain principles are followed. In effect, these principles reduce extraneous processing of information by the audience. One principle is that individuals learn better when words and pictures are presented, rather than when words alone are presented. This principle is termed the multimedia principle¹⁷ and is in line with the Dual Code Theory.

A second principle is that audiences demonstrate superior comprehension and retention when extraneous information is removed from the presentation.^{12, 16} This principle is referred to as the principle of coherence in multimedia learning. For PowerPoint in particular, this situation pertains to the amount and type of the information contained on the slide.

A third, critical principle is that of signaling.¹⁶ Learners benefit from presentations that highlight the organization of essential material. This principle mirrors Cognitive Load Theory in its emphasis on the need to clarify relationships that allow understanding of highly interactive information.

In this section, we assert that the common practice of PowerPoint slide is in conflict with the above principles. This conflict leads to two primary outcomes. First, the topic–subtopic structure, which was embedded in about two-thirds of the PowerPoint slides per set created, does not convey the interactivity among informational elements. Put another way, the topic–subtopic structure of PowerPoint violates the multimedia principles of coherence and signaling, and increases extrinsic cognitive load by requiring the audience member to expend valuable and finite working memory resources in order to comprehend relationships among concepts. Second, the topic–subtopic structure often leads the presenter to increase extraneous load by adding a great deal of non-vital information to the slide.

PowerPoint slides, as found in common practice, hide the connections between informational elements. In the common practice of PowerPoint slides, the phrase headline specifies a general topic, and each bulleted or sub-bulleted item appears as equally important and subordinate to the overall topic. At first glance, one would think that such a short headline would benefit the learner. However, a short headline instead leads authors to begin the creation of the slide with a topic such as “U.S. Energy Use.” Such a headline neither signals the audience to the perspective taken by the presenter on the topic, nor highlights the organization of information. Therefore, 85% of the slides in our study potentially concealed the perspective taken by the

presenter. In contrast, signaling and highlighting would occur with a headline such as “The U.S. has only 5% of the world’s population, but consumes 25% of the world’s energy.”

In addition, with the common practice of PowerPoint slides, the specific connections between the headline and each of the bulleted items, and the relationships between the bulleted items themselves, are not immediately apparent. This lack of connection violates the signaling principle as described above. In addition, the structure may inadvertently promote irrelevant processing of information by audience members, and therefore extraneous cognitive load, as they struggle to connect the meaning of the phrase headline and the body text. In our study, 65% of the slides contained a phrase headline with a bullet list. Therefore, it seems that slides conforming to common practice, as determined here, fail to optimally signal the connections between ideas and run the risk of lowering audience comprehension.

As an example of how the common practice of PowerPoint slides reduces the ability of audience members to detect informational interactivity, consider the public domain slide in Figure 4. Without having a defined perspective on the topic of “synthesizing diamonds,” the slide wanders from the opinion of people on synthetic diamonds, to the closeness of synthetic diamonds to real diamonds, to the history of synthetic diamonds, and then to the detection of synthetic diamonds by those who mine diamonds. In addition, the presenter’s decision to fill the bulleted textbox with text has led to the addition of redundant information. The slide violates the multimedia principle, the principle of coherence, and the principle of signaling.

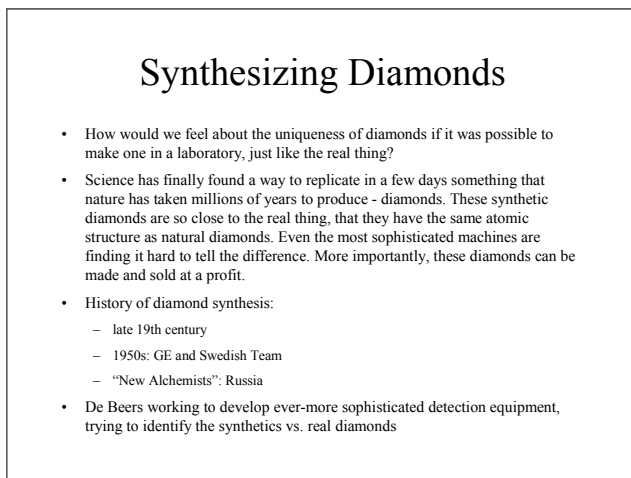


Figure 4: Common practice slide that follows the topic–subtopic structure.

Moreover, because the slide contains so much text, the presenter is likely to read the text on this slide, especially if the presenter is a novice in the field. This scenario violates an additional multimedia principle of *redundancy*, which states that “people learn more deeply from graphics and narration than from graphics, narration, and on-line text” (p. 183).¹⁶ Simply stated, this principle indicates that reading and hearing identical verbal information simultaneously is not helpful for audience members’ comprehension.

PowerPoint slides, as found in the common practice, have too much text on the slides. As mentioned, harsh criticism of PowerPoint’s presentation slide structure has recently surfaced in several popular publications: “Absolute PowerPoint,” *The New Yorker*¹; “PowerPoint Is Evil,”

*Wired*⁴; “Is PowerPoint the Devil,” *The Chicago Tribune*⁶; and “Research Points the Finger at PowerPoint,” *The Sydney Morning Herald*.⁸ A common thread is that slides often overwhelm audiences with information—a situation that John Sweller states as arising from placing too many of the spoken words on the slide.⁸

How does PowerPoint lead users to overwhelm slides with too many words? As suggested earlier, the answer lies in the program’s defaults. One problematic default is the bullet text default for the body of slides. Covering the middle and lower portions of the slide, as was shown in Figure 1, this text box default occupies 60 percent of the space on the slide master. By displaying such a large box, this default leads users, especially novices, to fill the slide with text. Doing so thus introduces extraneous cognitive load and increases the risk of violating the principle of redundancy.

What is the common practice for the amount of text on slides? As shown in Table 2, our survey reveals that the amount of text on common practice slides is high. For instance, the average number of words per slide for the conference slides was 33 words. In addition, because we knew how long the speakers at 2008 ASEE National Conference presented for, we could estimate the average amount of time spent on each slide. That amount of time was about 1 minute. Simply put, 1 minute is not enough time for an audience to read and comprehend 33 words on a slide *and* to listen to and comprehend the speaker, who is likely saying more than 100 words per minute.

Table 2. Common practice statistics on slide text.

Feature	Statistics	
	Mean	S.D.
Number of lines of text per slide	7.5	2.2
Number of words per slide	33	1.2
% of slides per set with graphics	42%	0.26
Number of slide sets considered	72	
Total number of slides considered	1381	

PowerPoint slides, as found in the common practice, do not contain images that promote optimal comprehension and retention. Because text is the default for presenting information on a PowerPoint slide, the structure begins in violation of the multimedia principle. Granted, many presenters do make efforts to include images on slides. In our survey of common practice slides we found graphics on 41 percent of the conference slides.

At first glance, it may seem that the addition of photographs, drawings, diagrams, and graphs would allow the topic–subtopic slide to accommodate Dual Code Theory and other research findings which favor the inclusion of images with text to bolster learning outcomes.^{14, 18, 19, 20, 21, 22} For instance, research shows that the use of relevant, labeled images can support conceptual understanding of principle-driven information in novice learners.²²

However, we contend that the images typically selected for topic–subtopic slides do not contribute optimally to learning. Simple inclusion of images does not by itself solve the problem. Logic holds that the most helpful types of images, in terms of promoting comprehension and

transfer of learning from text, either represent or explain concepts.^{23, 24} However, because a phrase headline identifies the topic, rather than makes an assertion about the topic, presenters often do not select the graphic that explains the information on the slide. Rather, presenters tend to choose a picture that, at best, replicates or depicts information already present on the slide. Moreover, because the large default text box in the body restricts the space for images, presenters compromise on the quality of the graphic and select images that represent only a portion of the content.

To assess the types of images in our survey of slides, we used a modified version of a classification system that was designed to catalogue pictures that accompany expository text.²⁵ Our system identified four levels of purpose that an image could fulfill: decorate, partially represent, represent, and explain. Decorative images were those deemed to be irrelevant to the text. Partially representative images identified portions of the slide’s content. Representational images represented or identified the main topic of the slide. Explanative images showed how the main principle, process, or system of the slide works. An example of an explanative image would be a flow diagram to show how energy moved through a system or a graph to show a key trend.

Images from slides in our survey were catalogued according to the above rubric. As can be seen from Table 3, a significant number of images in the common practice were found to be either decorative or partially representational. That is, either the images bore no relationship to the text (for example, a decorative piece of art) or they mirrored only part of the text (a photo representing only one bulleted item for example). What is important to remember from Table 2 is that only about 40 percent of these common practice slides even have graphics—the remaining 60 percent are just text. The incorporation of images from the common practice of PowerPoint slides therefore seems to run counter to the research on learning and multimedia presentation design, which emphasizes the importance of providing images that promote integration between concepts.

Not reflected in Table 3 are the decorative images from the use of PowerPoint default backgrounds, such as those shown in Figure 5. In our survey, we determined that 47% of the slide sets examined of slides used such a background. As asserted by Carney and Levin,¹⁹ such decorative images slightly reduce the comprehension by audiences.

Table 3. Common practice statistics on image level.

Classification	Definition	Statistics
Decorates	Not relevant to text	5%
Partially Represents	Represents only a portion of the slide’s content	15%
Represents	Represents the main topic of the slide	46%
Explains	Explains the slide’s main concept, process, or system	35%

In summary, PowerPoint slides, as commonly designed, violate important learning principles including the multimedia, coherence, signaling, and redundancy principles. These slides often create extraneous cognitive load for audience members and therefore lead to poor comprehension and learning outcomes.

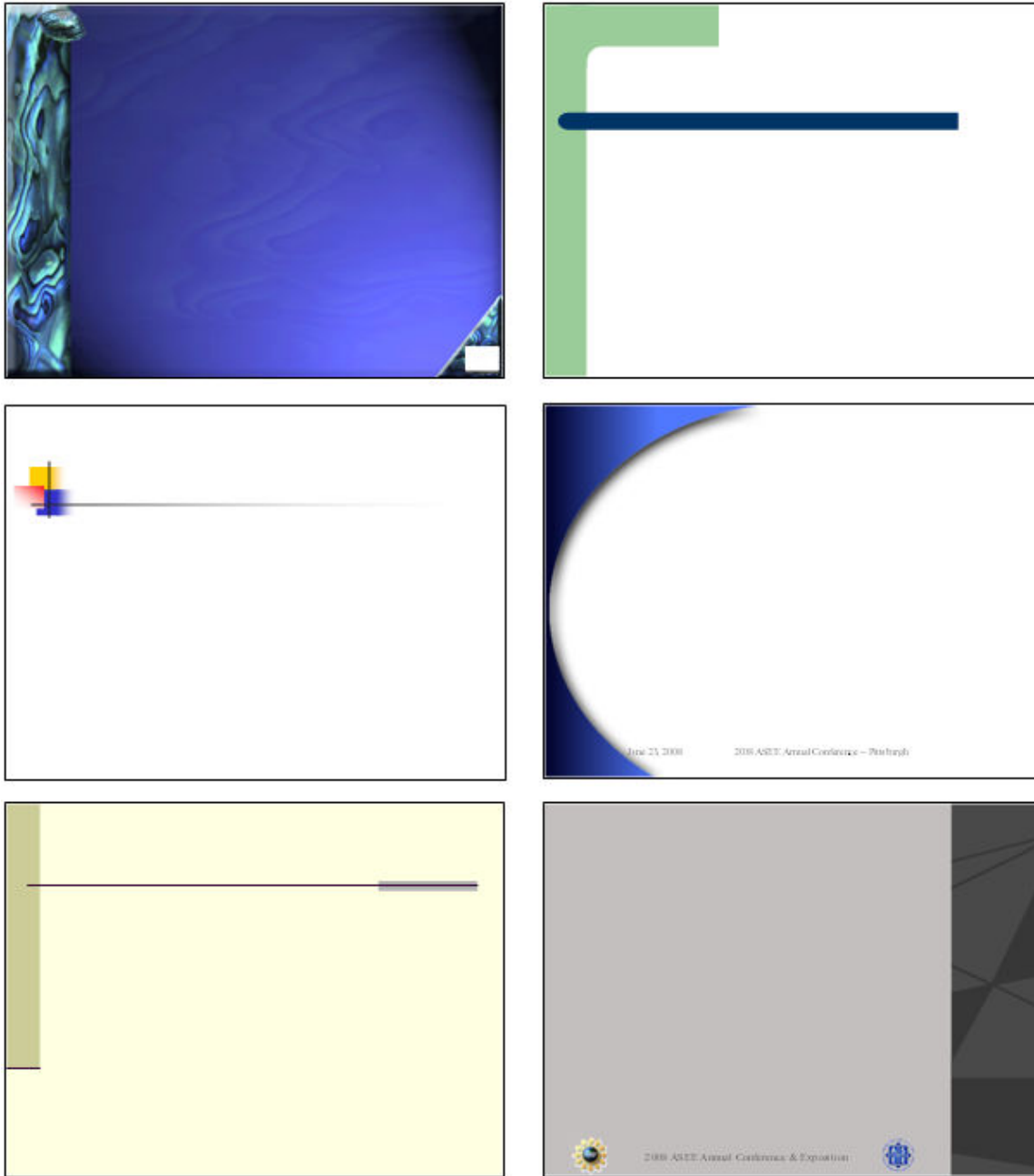


Figure 5: Sampling of PowerPoint backgrounds used by presenters at the 2008 ASEE Conference and Exposition. According to multimedia research,¹⁹ such decorative features reduce audience comprehension and retention of the content.

Conclusion

Recent articles in the popular literature have soundly criticized the topic–subtopic structure that is framed by the defaults of PowerPoint. However, the question arises whether presenters

actually follow those defaults. This paper has found that slides shown in research presentations at the 2008 ASEE National Conference and Exposition are strongly influenced by the defaults of PowerPoint in their design of slides. Our statistics indicate that about two-thirds of slides per presentation follow the topic–subtopic structure, which essentially consists of a phrase headline supported by a bullet list.

Following this structure leads to problems in orienting the audience to key information, conveying connections between important concepts, narrowing the topic to a manageable size, and including too much text on the slide. All of these factors increase the cognitive load experienced by the average audience member as he or she tries to understand the presentation. The net result for slides in the common practice is reduced comprehension and retention of information.

Following years of research in cognitive psychology, a number of important multimedia learning principles have been put forward. Instead of continuing to violate these principles by following PowerPoint’s defaults, presenters should consider using an alternative slide structure that adheres much more closely to these principles. One alternative would be the Assertion-Evidence slide structure,²⁶⁻²⁷⁻²⁸ which seeks to reduce unnecessary cognitive load while promoting connections among informational elements. As indicated by preliminary tests,²⁹ the result of adopting this structure could be superior comprehension and retention of the presenter’s intended message.

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