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Information Scaffolding: Application to Technical Animation

By

Catherine Claire Newman

a dissertation submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ENGINEERING – MECHANICAL ENGINEERING

in the

GRADUATE DIVISION

of the

UNIVERSITY of CALIFORNIA, BERKELEY

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Professor Michael Buckland

FALL, 2010

Information Scaffolding:  
Application to Technical Animation

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Catherine Newman

if you can help someone turn information into knowledge,  
if you can help them make sense of the world, you win.  
--- john battelle

## Abstract

## Information Scaffolding: Application to Technical Animation

by

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Information Scaffolding is a user-centered approach to information design; a method devised to aid “everyday” authors in information composition. Information Scaffolding places a premium on audience-centered documents by emphasizing the information needs and motivations of a multimedia document's intended audience. The aim of this method is to structure information in such a way that an intended audience can gain a fuller understanding of the information presented and is able to incorporate knowledge for future use. Information Scaffolding looks to strengthen the quality of a document's impact both on the individual and on the broader, ongoing disciplinary discussion, by better couching a document's contents in a manner relevant to the user.

Thus far, instructional research design has presented varying suggested guidelines for the design of multimedia instructional materials (technical animations, dynamic computer simulations, etc.), primarily do's and don'ts. The unique difference here is that Information Scaffolding is suggesting an initial methodology designed to address the informational and educational needs of a document's intended audience. Information Scaffolding is an adaptation of well-established user-centered design approaches applied to information design in an attempt to provide “everyday” authors with a flexible and yet structured procedure for how to construct “everyday” documents capable of improving knowledge transfer.

The Information Scaffolding method is characterized by 3-pillars. The first is a learning primer designed to inform “everyday” authors about a few key concepts related to learning, including the number of cells in the brain and the roles of prior knowledge and attention in learning. The second is a set of methods which help “everyday” authors begin to construct audience-centered documents, tailored to a unique audience. The two key methods for audience assessment are the concept inventory and the audience demography. The third is a set of 7 design heuristics which are suggested design principles aid the author with information design. These 7 principles are: Information Metaphor, Conceptual Chunking/Information Density, Wayfinding & Navigation, Prioritization of Key Information, Temporal & Spatial Relationships, Global & Local Perspectives and finally the use of Complementary Media.

This dissertation is an introduction to and analysis of the Information Scaffolding method as applied to the design and construction of short technical animation projects. This dissertation begins with an introduction to the foundations of the Information Scaffolding method. The second portion of the dissertation is devoted to the evaluation of the Technical Animation Research Study, which uses a combination of qualitative and quantitative methods. The dissertation concludes with a revision of the Information Scaffolding method presented in light of the study's results.

How and under what circumstances does the Information Scaffolding approach aid in the construction of technical animations? The evaluation of the Information Scaffolding method is a simple author-directed, user-centered approach to improved understanding, and begins in this dissertation by looking at the technical animation process and products from three perspectives:

1. Author Scaffolding, Scaffolded Design Implementation: How do the authors implement the Information Scaffolding Framework?
2. End Users/Intended Audience - Audience Perceptions & Comprehension. What are the perceptions and the degree of comprehension of the animations by audience members?
3. Content Analysis: What characterizes the content of the finished product?

Conclusions: When scaffolded projects were authored by students without formal scaffolding training, the scaffolded projects were more memorable than the unscaffolded projects (memory being the precursory step to learning). Participants also felt that the scaffolded projects provided a more complete description of the devices. Additionally, audience members estimated that they would need to watch scaffolded projects fewer times in order to be able to explain the assembly and operation of the described devices.

After the characterization and ranking of test bed Technical Animation projects, the major insight was that groups who had a small number of well articulated message goals ranked best in all measures, including audience perception and comprehension, project grade and content analysis.

The research study revealed opportunities for iterative improvement of the 2008 version of the Information Scaffolding methodology. The revised methodology includes: a learning primer reading requirement, a revamped set of questions for the audience demography, a document mission statement of purpose, and a more structured process for integrating the results of the concept inventory and audience assessment.

Six new considerations presented themselves as a result of this study: Project Framing, Project Storyline, Time Design, Vocabulary & Nomenclature, Misperception & Misconception, Visual Distinction. Each of these concepts is represented in the Information Scaffolding methodology in a form accessible to the “everyday” author.

## Table of Contents

1 Introduction

### Part 1. Information Scaffolding

2 Foundational Research

3 Information Scaffolding . Framework & Methodology

4 Prior Research Studies

### Part 2. Technical Animation Research Study

5 Technical Animation Research Study

6 Scaffolded Authoring

7 Quantitative and Qualitative Evaluation of Audience Perceptions & Comprehension

8 Content Analysis

### Conclusions & Future Research

9 Conclusions

10 Future Research

### Back Matter

References

Appendix 1. Information Scaffolding Worksheet

Appendix 2. CPHS Protocol Approval

## Table of Contents

1 Introduction		1
	FRAMING <i>INFORMATION SCAFFOLDING</i>	1
	DISSERTATION ROADMAP	2
<b>PART I. INFORMATION SCAFFOLDING</b>		
2 Foundational Research		
	INTRODUCTION	6
	TECHNICAL ANIMATION: DEFINITION	6
	UNIQUE REPRESENTATIONAL ADVANTAGES	6
	KEY MULTIMEDIA RESEARCH: IMPLICATIONS FOR TECHNICAL ANIMATION	7
	DESIGNING TECHNICAL ANIMATION FOR PEOPLE: INSTRUCTIONAL GUIDELINES	8
	CORNERSTONE THEORIES FROM COMMUNICATION AND LEARNING SCIENCES RESEARCH	9
	STRUCTURING OUR EXPERIENCE: CONSTRUCTIVIST LEARNING AND RELATED LEARNING MODELS	9
	MENTAL MODELS	10
	FRAMING THOUGHT	10
	COMMUNICATION: THE CHALLENGE OF THE CONDUIT METAPHOR	11
	USER CENTERED DESIGN	11
	AUDIENCE-CENTERED INFORMATION DESIGN, DECISION MAKING, SELF-DIRECTED LEARNING AND MOTIVATION	12
3 Information Scaffolding . Framework & Methodology		
	INTRODUCTION	14
	SECTION 1. LEARNING PRIMER	16
	ABOUT THE BRAIN	17
	REMEMBERING: The role of memory and the act of the remembering	17
	SHORT-TERM OR ACTIVE WORKING MEMORY	18
	LONG TERM MEMORY AND MEMORY MAINTENANCE	18
	ATTENTION	19
	PRIOR KNOWLEDGE	19
	COGNITIVE OVERLOAD AND COGNITIVE NOISE	19
	SECTION 2. AUDIENCE ASSESSMENT	21
	CONCEPT INVENTORY	21
	BLANK CONCEPT INVENTORY	22
	EXAMPLES	22
	AUDIENCE DEMOGRAPHY	24
	SYNTHESIS OF CONCEPT INVENTORY & AUDIENCE ASSESSMENT	24
	SECTION 3. DESIGN HEURISTICS	26
	Principle 1. Information Metaphor	28
	Principle 2. Conceptual Chunking/Information Density	29
	Principle 3. Wayfinding & Navigating	30
	Principle 4. Prioritization of Key Information	31
	Principle 5. Temporal & Spatial Relationships	32
	Principle 6. Global & Local Perspectives	33
	Principle 7. Complementary Media	34
	Designing Information for People: Additional Advice for Technical Animation Design	35
4 Prior Research Studies		
	INTRODUCTION	36
	Study 1. The Planetary Gear Set and Automatic Transmission Simulation for Machine Design Courses	36
	Study 2. <i>The Circuitviz</i> : A New Method for Visualizing the Dynamic Behavior of Electric Circuits	37
	Study 3. Computer-Aided Education for Magnetostatics,	37
	Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	37
	CONCLUSIONS	38



5 Research Study Experimental Design	
	INTRODUCTION 40
	DESIGN-BASED RESEARCH 40
	REPORTING DESIGN-BASED RESEARCH 40
	RESEARCH HYPOTHESIS 41
	RESEARCH TESTBED 42
	EXPERIMENTAL DESIGN & DATA EVALUATION 43
	ITERATIVE DEVELOPMENT METHODOLOGICAL CHANGES 45
6 Scaffolded Authoring: Information Scaffolding Design Implementation	
	INTRODUCTION 46
	CONCEPT INVENTORY 47
	AUDIENCE DEMOGRAPHY 48
	CONCEPT INVENTORY AND AUDIENCE ASSESSMENT SYNTHESIS 50
	COMPREHENSION 51
	SCAFFOLDING DESIGN PRINCIPLES 53
	SCAFFOLDING PRINCIPLE EXEMPLARS 53
	CHARACTERIZATION OF THE TOP SCORING PROJECTS 55
	QUANTITATIVE ANALYSIS: FELLOW PARTICIPANT REVIEW 59
	SCAFFOLDING PERCEPTIONS 60
	CORRELATIONS 61
	AUTHOR SCAFFOLDING CONCLUSIONS 64
7 Quantitative and Qualitative Assessment of Audience Perception & Comprehension	
	INTRODUCTION 66
	INTENDED AUDIENCE SURVEY 2009 67
	GENERAL PERCEPTIONS 67
	INTENDED AUDIENCE PERCEPTIONS 68
	PROJECT LENGTH 68
	PRESENTATION APPROACH 69
	COGNITIVE OVERLOAD 70
	COMPREHENSION 71
	INTRODUCTION QUANTITATIVE ASSESSMENT 72
	SUMMARY OF RESULTS NUMERICAL AVERAGES 72
	SURVEY ANALYSIS: DEVICE DESCRIPTION 73
	SURVEY ANALYSIS: PRESENTATION STYLE 73
8 Content Analysis	
	INTRODUCTION 75
	FACETS OF ANALYSIS 75
	1. INTENDED CONCEPTS 75
	2. FRAMING 76
	3. STORYLINE 76
	4. PART RELATIONSHIPS 76
	5. REGISTRATION 76
	6. VOCABULARY 76
	EQUATION 77
	UNSCAFFOLDED TECHNICAL ANIMATIONS 79
	COMPARING EXEMPLARY PROJECT 80
10 Conclusions	
	INTRODUCTION 82
	NEW RECOMMENDATIONS FOR TECHNICAL ANIMATION 91
	REVISIONS OF THE INFORMATION SCAFFOLDING METHODOLOGY 97
11 Future Research	
	NEXT STEPS FOR TECHNICAL ANIMATION RESEARCH 93
	EXPANSION OF INFORMATION SCAFFOLDING METHODOLOGY TO OTHER FORMS 96
References	
Appendix	

## List of Tables

Table 1. Scaffolding Principle Citations

Table 2. Principles for Reporting Design-based Research

Table 3. Technical Animation Study Experimental Design

Table 4. Author Indicated Scaffolding Principles

Table 5. Fellow Participant Review. Averaged Results by Project

Table 6. Scaffolding Principle Correlations

Table 7. Significant Scaffolding Principle Correlations

Table 8. Intended Audience Survey Participation Results

Table 9. Audience Rewatch Results

Table 10. Content Analysis . Ranking Equation

Table 11. Ranked Content Analysis Project Scores

Table 12 . Ranked Content Analysis Project Scores with Un scaffolded Projects Added

Table 13. Comparison of Top Ranked Projects

Table 14. Comparison of Top Ranked Projects

Table 15. Significant Scaffolding Principle Correlations

Table 16. Information Scaffolding Technical Animation Study Data Collection and Evaluations

## List of Figures

Figure 1. Blank Concept Figure 1. Blank Concept Inventory

Figure 2. Compound Bow Concept Inventory

Figure 3. Transfer Case Concept Inventory

Figure 4. Vacuum Cleaner Concept Inventory

Figure 5. Disassembled Chainsaw

Figure 6. Scene Title for M1 Rifle

Figure 7. Battery Installation Scene

Figure 8. Air Flow in Paintball Gun

Figure 9. PS2 Controller

Figure 10. Vacuum Concept Inventory

Figure 11. Intended Audience Worksheet

Figure 12. Electric Drill Audience Viewing Scenario

# 1 Introduction

FRAMING INFORMATION SCAFFOLDING

Information Scaffolding is a user-centered approach to information design; a method devised to aid “everyday” authors in information composition. A major portion of Information Scaffolding is motivating authors to re-frame the authoring process, viewing the exercise not as a simple documenting process (author-centered) but instead as a process of informing (audience-centered). Information Scaffolding (IS) places a premium on audience-centered documents by emphasizing the information needs and motivations of a multimedia document's intended audience. The aim of this method is to structure information so that an intended audience gains a fuller understanding of the information presented and is able to integrate knowledge for future use. Information Scaffolding looks to strengthen the quality of a document’s impact both on the individual and on the broader, ongoing disciplinary discussion, by better couching a document’s contents in a manner relevant to the user.

*to Document*, v 1648 1. trans. *To teach, instruct.* [OED]

Today, we all have experience as both users and creators of information. From the user-perspective the new challenge is not finding information but sorting it, selecting from it, and maintaining focus. Defining the means and methods for processing and prioritizing information for a world where time is scarce and the amount of information is overwhelming is an ongoing challenge. Information Scaffolding asks authors to acknowledge the potential challenges and constraints we all face when attempting to digest a document, to 'learn', and to participate more fully in this process by addressing some of the needs of the intended audience up front.

Not enough credit is given to the shape of information. Often it is the form, the embodiment, the 'nature' of the information, and what the information 'affords' us that supports and enables user-comprehension. Information Scaffolding leverages the design of information in an easy yet effective manner to address audience needs. Information Scaffolding isn't looking to dress up or 'sell' information, but instead acknowledge how much easier it is to learn when the information 'speaks to us'. When information 'resonates' with us, when the author has paid time and attention so that our efforts aren't spent grasping terms and symbols, when we don't find ourselves lost within a document, confused about what information has been taken in and where to go next - is when we can best learn. Information Scaffolding is born of the belief that the new and old meaning of information is to inform, rather than to document.

*Information.* 1387 I. 1. a. *The action of informing; formation or moulding of the mind or character, training, instruction, teaching; communication of instructive knowledge. Now rare.* [OED]

The development of the Information Scaffolding methodology outlined in this dissertation is an initial investigation into a set of approaches, tactics, and exercises, that take the multimedia information we construct (websites, research articles, technical animations) and imbue this information with an underlying structure, an embedded logic that better ties together the presented media (images, text, sound, motion, etc.) cogently for the intended audience. Information Scaffolding attempts to make multimedia documents more 'sensible', capable of being made sense of, allowing the information takeaways to closely parallel the author’s intended message goals and the information takeaways salient for future use.

Formally, Information Scaffolding structures information to facilitate comprehension by a range of interested users: with conscious consideration given to informational and instructional needs, abilities and values; as well as to the affordances of the medium and knowledge domains. The scaffolding of information should:

- Keep the big picture central and in focus
  - Organize and support the comprehension process
  - Place a premium on clarity, clear direction and minimizing confusion
- \*[adapted from McKenzie '99]

Information Scaffolding synthesizes research efforts in Engineering/Human-centered Design, Education and Information Science to provide an approach initiated by the author(s), to embed a complementary meta-cognitive layer to improve user-comprehension and long-term knowledge integration.

Information Scaffolding suggests simple heuristic methods for consideration by the “everyday” author to support audience-centered information design. Three facets characterize the Information Scaffolding process. Each is a necessary attribute from the user-centered perspective, complementing and informing the other two throughout the process.

Three facets characterize Information Scaffolding:

1. A simple framework of how the mind works and how people learn, key terms and language. Including information processing and cognitive overload.
2. An ability to assess the information needs and motivations of the document audience. Tools include concept inventories and audience assessment.
3. A set of simple design principles/suggestions from education, design & information science for the scaffolding and composition of information.

Information Scaffolding has implications for all forms of documents for both intra-disciplinary and cross-disciplinary communication. The initial application of Information Scaffolding is in the area of engineering design where the continual need to learn from, build upon and innovate design ideas, concepts and methods is necessary.

The Information Scaffolding approach was applied to a course at the University of California, Berkeley designed to teach technical animation techniques to undergraduate engineering students. Over the course of 3 years, a refined scaffolding process was included in this course to aid the course design project. This project requires teams of 2-3 people to create 5-10 minute technical animations using solids-modeling and surface-modeling software. During the semester the students were taken through an Information Scaffolding approach in order to design and develop audience-centered technical animations. The Information Scaffolding approach was applied during the spring semesters 2006, 2007, and 2008, with iterative development occurring between interventions.

DISSERTATION  
ROADMAP

This dissertation proceeds in two parts, comprising 10 chapters. *Part 1 - Information Scaffolding* begins by explaining the fundamental theories and research background which define the foundation of the Information Scaffolding methodology (Chapter 2). The full theory and method of Information Scaffolding is then presented (Chapter 3). To further frame the motivation of this work, prior animation research studies are reviewed and presented as counterpoints to the work presented here (Chapter 4). *Part 2 - Technical Animation Research Study* begins by explaining the experimental design of Information Scaffolding: Technical Animation Research Study, and is followed by four chapters of analyses. Finally, conclusions are drawn from the analyses done in the preceding chapters and followup research questions and thoughts for future research are recommended.

Chapter 1: Introduction. This document begins with a broad explanation of Information Scaffolding, a mission statement intended to begin a conversation about methods for imbuing every document with instructional design principles to encourage the strengthening of interdisciplinary and multidisciplinary communication. The introduction then specifically discusses the application of Information Scaffolding to technical animations.

Chapter 2: Literature Review. To better ground the presented research study, existing research regarding the use of dynamic multimedia for educational purposes is summarized, including the unique challenges of dynamic multimedia. Information Scaffolding is a synthesis of established research principles from Engineering Design Research, Information & Communication Theory and Learning Science Research. As a transition into the development on the Information Scaffolding methodology, the third section of Chapter 2: Literature Review presents an abridged version of key relevant concepts from Information Science and Education. Established guidelines for the construction of dynamic educational materials are summarized. Finally the criteria for the fusion of the Information Scaffolding principles and methods are described.

Chapter 3: Information Scaffolding is a complete portrait of the three facets of the proposed Information Scaffolding methodology. These three facets are a Learning Primer, tools for Audience Assessment and general Design Considerations for the meta-level design of technical animations. An essential premise in this research is that the success of the information scaffolding methodology is that the three facets are interdependent. The information scaffolding approach is meant to be a holistic approach to information design that does not provide a recipe or prescription or reduce the use of creativity by the document authors. [Newman '05, '09]

Chapter 4: The 2007 Hoffer meta-study [*Instructional Animations Versus Static Pictures: A meta-analysis*, Hoffer '07] summarizes 26 animation studies taking place from 1973 to 2003 and illustrates that an answer to the question “do dynamic presentations aid learning (conceptual change, knowledge transfer, etc.)?”, is inconclusive, citing flaws and wide variation in research methodology and a strong dependence on subject matter. Seven additional studies concluded after 2003 are then recounted. These studies provide case examples of scenarios where animation has provided a learning benefit, what is generally not covered is how the technical animation was constructed - including the pedagogical considerations, audience assumptions and dynamic affordances.

Chapter 5: Technical Animation Research Study describes the Information Scaffolding research methodology employed during the Spring 2008 and includes the use of a Design-Based research method, three Primary Research Questions, the Research Case and the iterative development of the study intervention. Also included in this chapter are: a description of the data measures collected and the methods of data analysis.

Ultimately this dissertation is interested in: how and under what circumstances does the Information Scaffolding approach aid in the construction of technical animations? The evaluation of the Information Scaffolding methods is a simple author-directed, user-centered approach to improved ‘understanding’, begins in this dissertation by looking at the resulting technical animation process and products from three perspectives:

1. End Users - Audience Perceptions & Comprehension. What are the perceptions and the degree of comprehension of the animations by audience members? This is covered in Chapter 6 and then again in Chapter 9.
2. Author Scaffolding. Scaffolded Design Implementation: How do the authors implement the Information Scaffolding Framework? This is covered in Chapter 7.
3. Content Analysis: What characterizes the content of the finished product? This is covered in Chapter 8.

Chapter 6: Scaffolded Authoring. Scaffolded Design Implementation looks at the scaffolding approaches each group of authors used to construct the finished technical animation. The primary data used to evaluate each group was a required written project supplement, which was a summary of each group's scaffolding process. This supplement included three sections: a concept inventory, an audience assessment and a checklist of technical animation meta-design principles. The success of the audience-centered scaffolding is reviewed from the perspective of a peer-assessment, to conclude the chapter and the analysis of the author scaffolding.

Chapter 7: Audience Perception & Comprehension. This chapter looks at the perceptions of the finished technical animation projects from the point of view of two sets of audiences. Qualitatively, the projects are reviewed using comments from an intended audience survey. Quantitatively, audience perceptions and comprehension are reviewed with a new set of audience members asking generalized scaffolding questions about perceived completeness and the ability of viewers to digest and translate the information contained within the technical animations. In addition these participants were asked to list five components or functions of the illustrated device. This was an attempt get at audience comprehension in a different way.

Chapter 8: Content Analysis uses a film studies approach to evaluate the finished technical animations. This content analysis looks at the storyline and content of the animation in conjunction with the framing of the subject matter. The content analysis also looks at the registration of key points, the use of vocabulary and the relationships between parts of the mechanical device.

Chapter 9: Conclusions presents the study's significant conclusions and is structured to address these questions:

1. Broadly, what characterized the most successful technical animation projects?
2. What conclusions can be drawn about comprehension?
3. Were the technical animation projects informed by the choice of audience and subsequent audience assessment in addressing the project message goals?
4. Scaffolded Design Principles. What conclusions were drawn from the initial scaffolding principles? and more?

Chapter 10: Future Research & Next Steps introduces the next steps for Information Scaffolding Technical Animation research and concludes with a discussion of how the Information Scaffolding methodology can be expanded into other forms of information composition.

# part 1

# information scaffolding

2 foundational research

3 information scaffolding: theory & method

4 related prior research studies



## 2 Foundational Research

INTRODUCTION Information Scaffolding is an approach to information design which is meant to complement an individual's existing authoring process. The full Information Scaffolding methodology, as practiced in the Technical Animation Research Study (Chapters 5 - 8), is presented in Chapter 3 in a form designed for authors interested in audience-centered information design. But before launching into the theory & method of Information Scaffolding there is important research which has informed the theory and which frames the application of the *IS* method to the construction of audience-centered technical animations. That work is presented here in Chapter 2 -Foundational Research.

INTRODUCTION While the use of the term Technical Animation varies widely, D.K. Lieu, a leading instructor of technical animation techniques, helps to define technical animation by emphasizing the desire for 'real' or realistic representations of time, motion and object appearance [Lieu, '04]. Often what distinguishes a 'technical' animation from another type of animation or dynamic representation may simply be the subject matter. If the subject or the intended message goals are technical or scientific in nature, then animation may fall into a technical category.

Formally, D.K. Lieu's definition of technical animations is: *"the sequential presentation of individual graphic images at a rate sufficient to convey an impression of real motion within those images. If the individual images have sufficient detail, and if the rate is sufficiently high, an illusion of real objects in motion can be projected. In some cases, the viewer can control the motion, as with the dynamic image rotation feature found in most solids modeling software programs. This feature allows a pictorial image of a solid object to be rotated and viewed from different angles in real time, giving the viewer accurate visualization of the part. In other cases, the animation sequences are pre-recorded, and particular sequences are replayed upon command."* [Lieu '04, '09]

UNIQUE REPRESENTATIONAL ADVANTAGES Technical animations are able to represent information in ways that are uniquely beneficial for the understanding of some scientific and technical subjects. Some of these advantages include:

- An ability to represent spatial and temporal dynamics in a repeatable manner. [Clark '05]
- "Aids cognition in that it can provide directional/procedural flow, emphasis, functional relationships and interrelationships among parts and systems as well as realistic simulations." [Dwyer '06]
- Simulating abstract phenomena to help describe complex/abstract concepts such as molecular bonding or wave propagation [Lieu '09]
- Offering an excellent means of presentation of technical information to non-technical audiences. [Lieu '04]
- A potential unparalleled clarity in the explanation of assembly and operation of devices. [Lieu '04]

This dissertation evaluates:

*5-10 minute technical animations illustrating the assembly and operation of a moderately complex mechanical device, composed of several mechanical parts, and constructed with different materials or material finishes. Additionally, the animation is required to specifically illustrate the aspects of the device's operation that are difficult to visualize or understand conceptually (airflow, magnetic field, fluid flow, microscopic material properties, etc.).* [Course E128: Advanced Engineering Graphical Communication. Department of Mechanical Engineering, University of California, Berkeley].

KEY MULTIMEDIA RESEARCH: As will be seen in this technical animation research study, the amount of information shown using multimedia dynamic representations can easily overshadow the author's primary message goals, if simply because the media is abundant.

IMPLICATIONS FOR TECHNICAL ANIMATION: Schnotz asserts, and as many may know from experience, "learners often underestimate the information content of pictures... thinking short looks or glances are enough to extract the relevant information" [Schnotz '01]. In the technical arena it is rarely the case that graphs, diagrams and now animations can be understood with short glances. In fact they often contain a wealth of information, embedded at/on many levels. Animations can be extremely helpful for engineering comprehension and abstract thinking because they can dynamically illustrate the movements of mechanical devices or the nature of chemical reactions or fluid flow. On the other hand, "animations can hinder knowledge acquisition because they sometimes reduce the demands on the learner's cognitive processing in an unwelcome way"[Schnotz '01][Schnotz '94].

Mayer represents the cognitive processing (or cognitive load) required to understand multimedia messages by defining three types of cognition:

1. *Essential Processing - the act of making sense of the presented material - including selecting, organizing and integrating words and selecting, organizing and integrating images.*
2. *Incidental processing - not required for making sense but occupies some processing effort. Technical animation examples: uses of background music, dynamic changes in color, scale or point-of-view.*
3. *Representational Holding - the effort required or necessitated in holding a mental representation in working memory over a period of time. [Mayer '01]*

In the case of technical animation, an audience member can be underwhelmed, but it is more often the case that they are overwhelmed. It is not typically the subject matter or the animation's level of detail which are overwhelming but the incidental processing required to sort out the bells and whistles which tend to "distract, disrupt or seduce" [Mayer '01]. This type of *Cognitive Overload* presents a very real barrier to comprehension. Minimizing the aspects of a message that over tax cognition (known as *Cognitive Noise - irrelevant or unhelpful distractions*) can reduce unnecessary cognitive load. *Cognitive Noise* often occurs in technical animations when either the information being presented is complex and thus requires a lot information to be presented at once or when extraneous information is present in one or more of the available modalities (visual, textual, auditory).

Cognitively, the learning and communication objectives may be hindered by:

- *Distracting - guiding the learner away from priority information*
- *Disrupting - the building of inappropriate links between important pieces of information.*
- *Seducing - with unrelated information, setting the learner on an unintended learning path.*

---[Mayer '01]

Common forms of *Cognitive Noise* in technical animations are:

- Misalignment of sound and motion
- Unnatural part interaction or motion
- Low resolution of sound
- Pixelated views (high compression)
- Overactive camera motion (shaky, jumpy)
- Low frame rate
- Extreme lighting conditions: too light or dark
- Overly cluttered environment

DESIGNING TECHNICAL ANIMATION FOR PEOPLE:	In 2006, Dwyer's animation study results showed that, "when all levels of learning [facts, concepts, rules/procedures, and higher order comprehension] are expected to occur at the same time, information overload occurs as a result of viewing and interacting with the animation, and the animated sequences and enhancement strategies become ineffective." [Dwyer '06]
INSTRUCTIONAL GUIDELINES	The highly regarded instructional designers, Levie & Fleming warn that, " <b>learning is more correctly attributable to well-orchestrated design strategy than to the inherent superiority of various media.</b> " [Fleming '93]. If animations are to be used as learning objects, it is imperative that the learning needs and style of the audience be addressed. As Duke & Pearson [Duke '02] emphasize in addition to the rudimentary transactional cognitive processing of information, audience members are making judgments (e.g., value, quality, etc.) about the information, bringing unique prior knowledge, individual thinking patterns and learning techniques to the experience.

In 1993, Park and Hannafin presented 20 empirically-based guidelines for the design of interactive multimedia for use both in educational and non-educational settings. Information Scaffolding is not focused specifically on interactive multimedia, but many of the well-researched principles can be applied to information design generally and to technical animation specifically. The most relevant of the 20 principles and their instructional implications are listed here:

- Principle 2. New knowledge becomes increasingly meaningful when integrated with existing knowledge.*
- Principle 3. Learning is influenced by the supplied organization of concepts to be learned.*
- Principle 4. Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task, and assumptions about the structure of knowledge.*
- Principle 6. Knowledge is best integrated when unfamiliar concepts can be related to familiar (known) concepts.*
- Principle 11. (future) Knowledge flexibility increases as the number of perspectives on a given topic increases and the conditional nature of knowledge is understood.*
- Principle 12. Knowledge of details improves as instructional activities are more explicit, while understanding improves as the activities are more integrative.*
- Principle 19. Metacognitive demands are greater for loosely structured learning environments than for highly structured ones. [Hannafin '93]*

Park and Hannafin then take these principles and use them to suggest considerations for the construction of information:

- Embed structural aids to facilitate selection, organization, and integration.
- Embed activities that prompt learners to generate their own unique meaning.
- Provide methods that help learners acquire knowledge from multiple perspectives and cross-reference knowledge in multiple ways.
- Provide prompts and self-check activities to aid the learner in monitoring comprehension and adapting individual learning strategies.
- Provide opportunities to reflect critically on learning and to elaborate knowledge; encourage learners to articulate strategies prior to, during and subsequent to interaction with the environment.
- Organize lesson segments into internally consistent idea units.

CORNERSTONE THEORIES FROM COMMUNICATION AND LEARNING SCIENCES RESEARCH

Key insights from communication theory and the learning sciences help to further frame the role that technical animations, and multimedia documents in general, can play in comprehension.

STRUCTURING OUR EXPERIENCE:

One way of looking at the general process of learning is to say that we construct meaning from the information available to us in our environment, combining this information with our relevant prior knowledge. This is what is referred to as the *constructivist theory of learning*

CONSTRUCTIVIST LEARNING AND RELATED LEARNING MODELS

This theory asserts that learning is not a passive process whereby learners can easily and verbatim assimilate the information in front of them. What is more, learning is not a linear process of simple knowledge collection, it is instead a complicated and convoluted process requiring effort and attention [Hatano '86][Lanham '06] [Spiro '88] [Schwartz '04]. Accurate and complete learning is further complicated by the number of personal and contextual factors.

From Wertsch, 1997, *Vygotsky and the Formation of the Mind*:  
 “When individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. This may occur when individuals' experiences are aligned with their internal representations of the world, but may also occur as a failure to change a faulty understanding; for example, they may not notice events, may misunderstand input from others, or may decide that an event is a fluke and is therefore unimportant as information about the world. In contrast, when individuals' experiences contradict their internal representations, they may change their perceptions of the experiences to fit their internal representations. According to the theory, accommodation is the process of reframing one's mental representation of the external world to fit new experiences.”

The constructivist learning perspective forms the foundation of Information Scaffolding in that the learning goals, capabilities and needs of the learners (audience) are central [Brown '89; Ackerman '96]. Absent of this perspective the design heuristics which define Information Scaffolding may be wrongly interpreted and misapplied.

Constructivist learning theory also strongly argues that information must be contextualized. “Decontextualised knowledge does not give us the skills to apply our understandings to authentic tasks because, we are not working with the concept in the complex environment and experiencing the complex interrelationships in that environment that determine how and when the concept is used.” [Jonassen '92] Typically, the role of animation for learning has been to teach declarative or procedural knowledge, but animation has the potential to leverage its unique attributes (coordination of motion, lights and sound, for example) to depict conceptually difficult subjects such as magnetism or fluid flow. The importance of context (in our case the situational, individual-historical and relevant contexts of the presented information) is also primary in that “The world, in which the learner needs to operate, does not approach one in the form of different subjects, but as a complex myriad of facts, problems, dimensions and perceptions” [Ackerman '96]. Thus the application of the acquired knowledge must be flexible enough for use in a range of situations in the future. A challenge as an author of multimedia information is to supply information with enough structure and built in learning “process” to contextualize facts and provide useful understanding, while still providing overall cogent information and compelling document design. The use of technical animation presents an additional set of challenges. Fleming suggests that for instructional document design, in general, this should be done by “...build(ing) relationships between content and objectives and learner’s needs and desires, explicit statements about how

content builds on existing skills or knowledge, analogies and metaphors to connect to learner's prior knowledge of processes, concepts and skills, already familiar to the learner. Motivation is greater when instructional objectives align with learner's goals, indicate applications and further use" [Fleming '93].

MENTAL MODELS How our minds structure a topic can be considered the Mental Model of that subject. Mental models are coherent structures for understanding things. Lambert and Walker [Lambert '95] define a mental model as - "an individual's existing understanding and interpretation of a given concept, which is formed and reformed on the basis of experiences, beliefs, values, sociocultural histories, and prior perceptions. It typically refers to internalized representations of a device or idea held in the mind of one or more persons." [Jensen '05] For most it is difficult to articulate our whole "understanding" of a subject or topic because our grasp of a subject contains information in many modes, from many different experiences, in different areas of our brain.

Practically, how information is structured and represented (stored and organized) in our minds dictates how what we've learned can be accessed in the future. As Jensen says, "Trying to organize a significant body of knowledge is a challenge. It is reasonably easy to learn something that matches or extends an existing mental model, but if it doesn't match, learning is very difficult." [Jensen '05]. This reemphasizes what the Constructivist view of learning points out, learning, especially that which in some way contradicts our understanding of a subject or the world, is difficult. In part some of this challenge is derived from the nebulous and unique organization of any given subject in our minds.

When new information jives with our existing view of the world (mental model) it is relatively straightforward to integrate it with what we know. Unfortunately, when new information is incompatible with our existing model, even if this current model is faulty, incorrect or lacking in key detail, this new information can be and is often easily dismissed as anomaly. Expanding an existing mental model to include new information, scenarios and caveats, requires conscious consideration and extra attention.

Consider the implications for information design due to the existence of the multiple individual mental models contained by any given audience. It is easy for authors to take what they write, say or depict as fact – but these facts are based on the prior knowledge and mental models of an individual (the author). Indeed, both the understanding of a subject by the author as well as the mental representations of the audience must be taken into account. Compound the variations of mental models with the fact that most subjects on a professional level contain a combination of topics, amplifying the learning challenges for any given audience. [Linn '00, '04]

Jensen, like Fleming and most educational researchers, emphasizes understanding the intended audience, "finding out what students already know and asking them to make connections to another more accurate model is how the real learning process begins" [Jensen '05], which is in line with the objective of Information Scaffolding: to foster a community of learners [Brown '94] through improved communication between author and audience.

FRAMING THOUGHT One approach to begin addressing the instructional design of technical animation is to consider how the animation is *framed*. Not only how the use of the animation is framed (the context of use) but how the ingredients (the units of information used to comprise the large instructional message) are positioned in terms of the greater message and in relation to each other. Fillmore identifies framing as the structured ways of interpreting experience – the mental actions taken "in perceiving, thinking and communicating". "Another important notion in writings on language understanding is that of a speakers/hearer's ongoing model of the world, this conceived of as some kind of network of interlinked relationships representing bits of knowledge and the ways in which these bits of knowledge are integrated into a more

*or less coherent model or image of the world. Associated with this concept is the view that in an act of communication, one person affects the content of another person's world model... This model or image is thought of as including a record of the individual's beliefs about the world, a filtered and partly interpreted record of his past experiences, a current register of information about his position in space, time and society together with his version of the world-models of the other relevant people in his environment.*" [Fillmore '76] Especially in addressing the educated non-expert, as is the intent of *Information Scaffolding*, the wealth of knowledge accumulated over a lifetime by the members of an intended audience must be considered to the extent possible.

COMMUNICATION: In Reddy's seminal 1979 paper, he denounced the concept of the Conduit Metaphor, the yet  
 THE CHALLENGE unanalyzed use of physical metaphor we rely on heavily for communication and its implications  
 OF THE [Reddy '79]. Consider the prototypical phrase "the meaning is in the words" (or that the one  
 CONDUIT meaning or interpretation of any sentence or information is in the words). Implicit in this simple  
 METAPHOR statement is no matter how I chose to say or write something, the words will act as a conduit,  
 transporting my meaning exactly to another person (or persons in the case of an audience). We  
 know this is simply not the case – miscommunications and misunderstandings are commonplace. If  
 this were not true there would be no need to ever repeat or reiterate. In 1976, Furnas asked  
 subjects to name common cooking objects. The likelihood that two people (subjects) would give the  
 same word for the same object was less than 20%. Using a different name for the same object or  
 concept can be called synonymy [Furnas '76]

Take for example the perfectly illustrative example made by Fillmore, "If you were going to describe the term 'breakfast', how would you do it? Would you describe it as a meal in the morning? As the first meal of the day? As the meal after a long sleep? And what if you only ate one meal a day would that be breakfast?" [Fillmore '76].

We know that people will say the same thing differently from one instance to the next. It is a fact of life.

Now consider the author-audience pairing, what is the likelihood that an author will explain a concept in the same way that each audience member understands it? The permutations are overwhelming, but the Information Scaffolding method is designed to at least help to structure, if not to simplify, this process.

USER- User-Centered Design is an approach to design, a philosophy which takes the needs and  
 CENTERED considerations of the user into account. These needs become the initial driving force and continue  
 DESIGN to motivate design decisions throughout the process. Starting in the 1980's these user-centered  
 methods began to become codified, and are now a discipline of study in schools. There are a host  
 of user-centered design methods, some more applicable to certain design scenarios than others  
 and, to the same extent, the selection of methods is a function of the designer(s)' approach to  
 design. [Beckman '07]

User-centered design can be applied to the design of products, to the design of websites and to the design of information and in many cases this is already being done. We see it in the design of websites where design rules of thumb have quickly become established, but we also receive the benefit of such information design from many familiar sources of information - books, newspapers, photo essays, movies. These familiar sources have benefited in the past the existence of editors and designers. [Newman '01]

Today the "everyday" author is expected to be author, editor and now information designer. This is where Information Scaffolding comes in. IS takes a meta-design approach to aid "everyday"

authors in constructing user-centered documents. The aim is to maximize the impact of an author's efforts while limiting the negative impact on the the author's current process.

One aspect of note when comparing the Information Scaffolding method to other methods which emphasize the 'user' in user-centered design, is in addressing an 'audience'. Addressing an audience presents a particular challenge in that no audience can ever be truly homogeneous. There are always going to be differences of perspective, learning style, educational background, and information scenarios among the members of the audience. The Information Scaffolding method provides resources to specifically address the audience-centered facet of information design.

AUDIENCE-CENTERED  
INFORMATION DESIGN.  
DECISION MAKING, SELF-  
DIRECTED LEARNING AND  
MOTIVATION

Also now consider that technical animations rely very little on the use of text or spoken word, making the communication challenge ever more present. How can an "everyday" author hope to ensure that her/his meaning is interpreted appropriately? The presence of the conduit metaphor is further argument for a user-centered approach to "everyday" information design. [Blauvelt '03] [Tufte '01] [Gibson '77]

With the dozens of ways to present information to a host of audience-types, the author's choices may be simplified when informed by the motivations, needs and preferences of the intended audience. Rouet, et. al., write in their introduction to *Multimedia Learning*: "First, decision making is an intrinsic component of the learner activity, especially in constructivist settings. ...There is a growing body of evidence that decision-making is strongly influenced by a person's knowledge, values and goals. And, as evidenced in [Dr. Patricia] Wright's paper, such individual characteristics interact with the affordances of the information system, e.g., how the information categories are displayed on the computer screen. Using simple examples, Wright shows that design matters at all levels, from the global organization of the system to the shape or colour of individual icons. Interestingly, Wright echoes [Prof. Wolfgang] Schnotz's caution about multimodal and dynamic displays: Such complex compounds may support some cognitive processes but they may interfere with others." [Rouet '01]

The Dekeyser study calls for explicit consideration of the learner's needs in the earliest design stages. Despite the evidence for this need, and wide acknowledgement by the multimedia education community, the implementation has "still to be turned into facts in the multimedia industry". [Dekeyser '00, pg. 7]. This is also an accepted belief in the education and design communities but the adoption into "everyday" practice by non-design and educational professionals is not systemic.

#### *Self-directed learning*

Wright identifies the term *self-directed learning*, to indicate the subtle choices a person makes as she or he takes in information when constructing knowledge. Documents such as websites, technical animation, etc., require a type of learning which is highly self-directed. Once an author hands off a document (publishes), the reach of the author may be great, but the recurring input of the author is rare and at this point learning becomes primarily self-directed. [Wright '92, '99]

Again this is particularly true for technical animations, where easy distribution is found online and the context for the animation's viewing is constantly shifting. It may be advantageous for the author to consider the primary context during which the audience will view the animation. [Jonassen '99, '02]

Dekeyser shows that students do tend to use information differently as a function of their preferences or style, arguing for the use of multiple representations which afford multiple learning processes. "However, redundancy or illustration alone are not enough to make alternate representations efficient." She comments that multiple representations must encourage

“constructive friction”, i.e., an incongruence between formats that will result in a pedagogically-relevant additional processing on the part of the student.” [Dekeyser ’00]

The motivations and preferences of the audience should not be left only as a secondary consideration when designing a document, as it plays a most important role in the effectiveness of learning and information transfer. “Learners will not naturally engage appropriate cognitive processing” [Fleming ’93]. Further, the strategies a learner employs from the available toolkit of learned strategies is strongly influenced by a document’s design.

**Information Scaffolding asks authors to consider placing an emphasis on audience need and the resulting information sequence rather than defaulting to the structure of the author’s understanding as a means for presenting information.**

In addition to an audience-member’s learning-style preferences and prior knowledge, it is known that effective learning increases with engagement. Take the familiar experience of reading a page or pages and then thinking - what did I just read? We are very capable of taking in information without integrating it, without learning – only passively and superficially processing the information in front of us.

The ACTIVE PROCESSING ASSUMPTION of learning, states: “people are more likely to understand material when they can engage in active learning by mentally representing the material in words and in pictures and by mentally making connections between the pictorial and verbal representations. It is not good enough to deliver information to the learner; instructors must also enable and encourage learners to actively process the information.” [Clark ’03]. A challenge is producing information in a way that helps and encourages the audience to fully engage in the information we present. A further challenge with the use of animation is asking audience-members to engage with the animation in the appropriate way: beyond the bells and whistles. Information Scaffolding includes embedding aids within a document that encourage appropriate active information processing. Examples of these embedded aids include: embedded strategic pauses in the material, explicit references to relationships between information chunks, and directly signaling key information to the audience.

Clark warns that neglecting the active processing component of information design encourages shallow learning, including not connecting new information to prior knowledge or to other information contained within the document. [Clark ’03]. From one perspective this type of effort can be seen as time lost or time wasted both for the author and for the audience, which is another important consideration when addressing adult audience members.




# INFORMATION SCAFFOLDING

## Framework & Methodology

INTRODUCTION *Information Scaffolding* structures information to facilitate comprehension by a range of interested users; with conscious consideration given to the user's informational and instructional needs, abilities and values; as well as to the affordances of the medium and knowledge domains.

The scaffolding of information should:

- Keep the big picture central and in focus
  - Organize and support the comprehension process
  - Place a premium on clarity, clear direction and minimizing confusion
- \*[adapted from McKenzie '99]

*Information Scaffolding* synthesizes research efforts in Engineering/Human-centered design, Education, and Information Science to provide an approach, initiated by the author of any multimedia document, designed to embed a complementary meta-cognitive layer within the presented information with the aim of improved user-comprehension and long-term knowledge integration.

*Information Scaffolding* suggests simple heuristic methods for consideration by the “everyday” author to support audience-centered information design. Three facets characterize Information Scaffolding (*IS*):

1. A simple framework of how the mind works and how people learn, key terms and language, including information processing and cognitive overload.
2. An ability to assess the information needs and motivations of the document audience. Tools include concept inventory and audience assessment.
3. A set of simple design principles/suggestions from education, design, and information science for the scaffolding and composition of information.

Information Scaffolding has implications for all forms of documents and especially in cross-disciplinary communication. I have chosen the initial application of Information Scaffolding to be in the area of engineering design where the continual need to learn from, build upon and innovate design ideas, concepts and methods is necessary. The Information Scaffolding methodology

includes three pieces designed to inform the construction of audience-centered documents, including a Learning Primer, Audience Assessment, and a set of Design Heuristics.

These three facets of the Information Scaffolding Methodology are presented in the following sections. Examples from the completed research study are embedded to illustrate key points.

Section 1. Learning Primer: Before the results of the Audience Assessment or the Design Heuristics can be applied a basic understanding of both how learning works generally (key concepts of learning) and the individuality of every person's learning process must form the foundation of a *scaffolded* document. The key educational concepts covered in this chapter are: *about the brain, re(member)ing, attention, prior knowledge, and cognitive overload*. Each of these short excerpts only covers the surface of each topic.

Section 2. Audience Assessment: This section introduces an adapted *Concept Inventory*; the purpose of which is twofold: to help the authors both identify the primary and secondary message goals and, to articulate the underlying concepts that make up a document's subject. This section also provides some aids for *Audience Assessment*; these aids are rooted in the tradition of user-centered design. Finally, this section synthesizes the products of the *Concept Inventory* and the *Audience Assessment* are synthesized for use later during the document design phase.

Section 3. Design Heuristics: The purpose of this chapter is to present 7 Design Heuristics or frameworks with which to think about the organization, construction and design of a document for improved user comprehension. The use of the design heuristics still require conscious creativity on the part of the author to design documents which are audience rather than author-centered. The 7 design heuristic principles are:

- 1.: *Logic Model / Information Metaphor*
- 2.: *Conceptual Chunking*
- 3.: *Wayfinding & Navigation*
- 4.: *Prioritization of Key Information*
- 5.: *Temporal & Spatial Relationships*
- 6.: *Global & Local Perspectives*
- 7.: *Complementary Media*

**1.**  
**LEARNING**  
**PRIMER**

There are a few essential concepts from education, terms we have all heard but that we can benefit by knowing just a bit more, hopefully applying what we learn to how we approach document construction. The next several pages are a general introduction to some familiar learning terms and are organized into five categories:

ABOUT THE BRAIN

RE(MEMBER)ING

ATTENTION

PRIOR KNOWLEDGE

COGNITIVE OVERLOAD & COGNITIVE NOISE

The following short learning primer is comprised of excerpts from leading educational researchers listed below:

**Eric Jensen.** Teaching with the brain in mind [Jensen '05]

**Dr. Mel Levine.** A Mind at a Time [Levine '02]

**Richard Mayer.** Nine ways to reduce cognitive load in multimedia learning. with Moreno, R. Educational Psychologist, 2003. [Mayer '03]

**Wolfgang Schnotz.** Sign Systems, Technologies, and the Acquisition of Knowledge. Multimedia Learning-Cognitive and Instructional Issues. 2001. [Schnotz '01]

**Parkhurst & Dwyer.** An experimental assessment of students' IQ level and their ability to benefit from visualized instruction. Parkhurst, P.E., Dwyer, F.M. Journal of Instructional Psychology, 1983 [Parkhurst '83]

**George Miller.** The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. The Psychological Review, 1956, vol. 63, pp. 81-97 [Miller '56]

ABOUT  
THE BRAIN

The act of learning is built foremost on the physiology of the brain's makeup. Jensen starts his book, *From Teaching with the Brain in Mind*, by emphasizing,

*To begin – the number of brain cells can differ from individual to individual by Billions, and these differences are distributed in different regions of the brain. So while we all have a brain its composition is slightly different. This is right in line with what we all know from our own experience, every person is individual, every person is different. Different in how we process information, in how we think and in how we learn. Key Attributes About the Brain,*

- The brain changes constantly (adapting etc.)
- The structures of the brain compete and cooperate (optimize)
- But the point is that the brain is dynamic and versatile.

*The brain has been broken down into areas and structures but the brain as a whole manages to in the least, hear see smell touch breath, maintain short term and long term memories, process language, purposeful activities such as judgment creativity problem solving and planning, etc. [Jensen '05]*

REMEMBERING  
The role of  
memory and  
the act of the  
remembering

We should bear in mind that the content of our brains and the arrangement of these contents changes daily. What we 'know' is based on a concoction of our brain make-up: what we remember and how we remember it, and how that information is stored and retrieved (prior knowledge). It can be said that in order to learn we need to remember. Three processes/phases of memory include:

1. Encoding of Memory
2. Maintenance of Memory
3. Retrieval of Memory

Sustainable learning involves all three of these stages - otherwise learned information and memories are lost. In the 1930's and 1940's it was thought that our brains recorded our life (videotaped). But our brains do not record our lives. Memories in fact are far more complex, amorphous and changing. Again Jensen adeptly summarizes memory and the role of memory in learning.

*There is no single, all-purpose 'resting' location for all our memories. Our best learning and recall involves multiple memory locations and systems (Schacter, 1992). The fact that memory resides in so many different locations in the brain means that a single event, such as teaching a class, will activate multiple pathways: What someone saw will be stored in one area of the brain, what someone said and heard will be stored in a different area of the brain, and so on. When we recall memories, our brain has to reconstruct the fragmented 'Humpty-Dumpty' memory pieces (Shimamura, 2002) and make sense of them.*

*Memory has limitations in both time and capacity. These limitations are expressed in descriptions of our short-term or working memory. A time-sensitive process beholden to the rate of information coming in, working memory is a critical contributor to cognition and intelligence (Jonides, 1995). An item in working memory usually lasts for 5 to 30 seconds before either disappearing or being reactivated. The capacity limitations of semantic memory are influenced by both the strength of associations and the sheer quantity of items. Working memory capacity depends on: rate, meaning, strategy, novelty, primacy, recency, age of learner. We remember information better in chunks than in the form of random, single thoughts, words or ideas or groups of unrelated ideas. Advice - compare and contrast material, summarize what has (sic) learned, leverage non-linguistic representations, analyze and critique the material, consider material from different points of view, group and regroup material into different categories.*

---Eric Jensen, *Teaching with the Brain in Mind* 2005

SHORT-TERM OR  
ACTIVE  
WORKING  
MEMORY

Short-term or working memory, is a specific facet of memory. Mel Levine, in his book, *A Mind at a Time*, offers us an understanding of short-term memory including the many conscious and unconscious intermediate steps involved in learning. [Levine '02]

**Short-term [for working] memory** also serves as one of our mind's relay stations. As chunks of data enter our minds, we can send them to long-term memory for later use, use them right away and then forget them, or make use of them and then save them for future use. Or, of course, we can simply forget the information and do nothing with it. Such options have to be exercised with breakneck speed - in less than two seconds - unless, of course, you apply for an extension. You can extend the life of data in short-term memory in several ways: whisper it under your breath, form pictures in your mind's eye, if it is visual you can put it into words, thereby lengthening the amount of time that short-term memory plays host to the new inputs.

**Working memory** lets a child remember the stuff at the top of a page while reading the last few sentences of that page. **Working memory** accomplishes four specific duties:

1. Providing mind space for the combining or developing of ideas - so, for example, you can retain the beginning of an explanation while listening to the rest of it;
2. Offering a mechanism for holding together the parts of a task while engaged in that task-so, for example, you can remember where you just put down the scissors while wrapping a birthday present;
3. Making available a meeting place where short-term memory can get together with long-term memory - so, for example, you can remember the question you were just asked while trying to search memory for its answer; and
4. Serving as a place to hold multiple immediate plans and intentions - so, for example, you can stop for gasoline on the way to the mall without forgetting that you were going to the mall to buy some t-shirts. Let's elaborate on each of these active working memory traits.

---Mel Levine, *A Mind at a Time*

LONG TERM  
MEMORY AND  
MEMORY  
MAINTENANCE

*Long Term Memory is so enormously vast that there has been debate over whether information ever gets lost from long-term memory or whether information ever gets lost, when we can't remember something, it is simply lost in long-term memory. [A Mind at a Time. Mel Levine. '02.]*

"Why do we have to 'work' to maintain memories?", Daniel Schacter [Schacter '01] poses rhetorically. Many of us assume that once we 'know' something or have experienced it, that it is remembered.

The answer to Schacter's question is simple: "*Memories are malleable. As a general rule, most of what we are exposed to we don't remember. Of the things we don't remember, it is highly unlikely that they will remain in our memories intact.*" [Schacter '01]

In fact, the quality of a memory is impacted by factors such as: initial inattention, suggestibility, misattribution, bias, and persistence.

In addition, *because attributes of particular memories become strengthened by use, greater frequency of activation will influence them. If the information retrieved is faulty and left uncorrected, the resulting "false" memory will be strengthened. In other words, we may need to make even greater efforts to ensure that students retrieve and maintain accurate memories.* ---Eric Jensen, *Teaching with the brain in mind 2005*

The challenge is to systematically (and by design) file information in our memory such that we have access to it when we want or need it. In terms of learning and information transfer, the indication of portions of information which are new (must be encoded), old (to be recalled & refreshed) or maintained (refreshed), is a worthy exercise.

ATTENTION The section above alluded to the importance of attention in remembering. Levine and Jensen, frame the role and importance of having the user's attention.

*Attention is at work throughout the waking day. The attention controls directly the distribution of mental energy within our brains, so that we have the wherewithal to finish what we start and stay alert throughout the day. Other controls of attention slow down our thinking so we can plan and complete tasks competently and efficiently. --- Mel Levine, A Mind at a Time 2002*

*In the process of meaning-making, either you can have your learners' attention or they can be making meaning, but never both at the same time. Meaning is generated internally, and it takes time. External input (more content) conflicts with the processing of prior content and thoughtful reflection. Students rarely get training in how to be calm, thoughtful, or reflective and they are given little time to practice these skills in class. **Guidelines for direct instruction of new content. An appropriate amount of direct instruction of new content for Adult Learners is 15-18 minutes.***

---Eric Jensen, *Teaching with the brain in mind 2005*

PRIOR KNOWLEDGE Another attribute of how people learn is the Prior Knowledge already residing in our brains. *Much of what our brain is - is what we know. Relating prior knowledge [to new learning] is the single most powerful influence in mediating subsequent learning. [Parkhurst '83]*

Aspects of Prior Knowledge to bear in mind, again from Jensen,

- *All students will have some prior knowledge, even if it's just random or unconscious learning.*
- *Prior knowledge fundamentally influences whether and how a student will gain an accurate or deep understanding of the topic. [Altman '02]*
- *Prior knowledge is personal, complex, and highly resistant to change.*
- *The best way to teach is to understand, respect, and build on the student's prior knowledge*  
---Eric Jensen, *Teaching with the brain in mind 2005*

COGNITIVE OVERLOAD AND COGNITIVE NOISE In the section of Short-Term memory, we established how the brain tries to juggle and sort the barrage of information we are faced with during our waking hours. Specifically when needing to process multimedia information, *Users can underestimate information content of multimedia. [Multimedia] can hinder knowledge acquisition by reducing demand on the learner's cognitive processing in an unwelcome way [Schnotz '01]*

Cognitive Overload is when the ability to process information is impeded due to excessive demands on a person's working memory, as each person has an upper bound to their processing capacity (approx 7+/-2 bits of information at a time- [Miller '56]).

Attempting to understand a multimedia message requires three levels of cognition:

1. *Essential Processing* - the acting of making sense of the presented material - including selecting, organizing and integrating words and selecting, organizing and integrating images.
2. *Incidental processing* - not required for making sense but occupies some processing effort. example: background music, changes in color.
3. *Representational Holding* - the effort required or necessitated in holding a mental representation in working memory over a period of time.

---Richard Mayer, 2003

Cognitive Overload presents a very real barrier to comprehension. Minimizing the aspects of a message that overtax cognition (known as Cognitive Noise) can reduce unnecessary cognitive overload.

Cognitive Noise often occurs in technical animations when either the information being presented is complex and thus requires a lot information to be presented at once OR when extraneous information is present in one or more of the available modalities (visual, textual, auditory).

- *Distracting: guiding the learner away from priority information.*
- *Disrupting: the building of appropriate links between important pieces of information.*
- *Seducing: with unrelated information, setting the learner on an unintended learning path.*

---Richard Mayer, 2001

Common forms of Cognitive Noise in Technical Animation are:

- Misalignment of sound and motion
- Unnatural part interaction or motion
- Low resolution of sound
- Pixelated views (high compression)
- Overactive camera motion (shaky, jumpy)
- Low frame rate
- Extreme lighting conditions: too light or dark
- Overly cluttered environment

## 2.

**AUDIENCE  
ASSESSMENT**

Having insight into the audience a document is addressing and how that audience will interact with the content increases the likelihood that the audience will successfully make sense of the message and, in fact, may make the document planning easier. In addition, the creation of dynamic multimedia documents such as technical animations, require the conscious coordination of multiple information streams (sound, motion, etc.) along with the information message aims of the authors. The effective use of the available tools for communication requires understanding what needs to be communicated, and to whom. This section briefly covers a three phase process to help authors articulate what information must be scaffolded and for whom:

**CONCEPT INVENTORY**
**AUDIENCE DEMOGRAPHY**
**EFFECTIVE SYNTHESIS FOR AUDIENCE ASSESSMENT**
**CONCEPT  
INVENTORY**

Traditionally, a concept inventory is:

*“a multiple choice test designed to evaluate whether a person has an accurate and working knowledge of a specific set of concepts [1]. Concept inventories are built in a multiple choice format to insure that they can be scored in an objective manner. Unlike a typical multiple choice test, however, both the question and the response choice are the subject of extensive research designed to determine both what a range of people thinks a particular question is asking and what the most common answers are. In its final form, the concept question is presented both a correct answer as well as distractors, that is, incorrect answers based on commonly held misconceptions.”* [http://en.wikipedia.org/wiki/Concept\\_inventory](http://en.wikipedia.org/wiki/Concept_inventory). [Evans '01, Libarkin '08]

The most famous Concept Inventory is the Physics Concept Inventory developed by Prof. Hestenes over the course of 15 years. Over this period of time it changed and was refined significantly. [Hestenes '92]

However, concept inventories do not exist for the majority of subjects for two reasons: 1. They are extremely well vetted by expert teachers in the field, requiring considerable time and effort and 2. Unlike physics, most topics are nebulous, sometimes changing and often still open to debate.

Information Scaffolding leverages the approach of the concept inventory to bring shape to the unique concept we are attempting to articulate with our information, in its given form, within the given context and for our intended audience.

In a document there will be both information that we present that is well established and new. The goal of an author-constructed concept inventory (or concept survey) is to establish a list of items that the author feels bounds or brings shape to the unique subject of the document. A good rule of thumb is to begin with 15 items in a first concept inventory draft.

There are a number of ways to approach the construction of a concept inventory but ultimately the objectives are, to bound the scope to the material presented and a clear perspective on where the audience is coming from.

*The purpose of a concept inventory is to articulate a set of individual concepts that together describe the knowledge and information “contained” by the document you will construct. A concept inventory is a list of items including but not limited to; key information, related learning principles and background, cultural relevance, and common misconceptions. The purpose of this exercise is to gain a detailed understanding of the necessary knowledge contained within and in support of your message goals. Your concept inventory will not be complete in the sense that will cover everything, instead will be a brief synopsis of the concept, as you understand it.*



Step 1. List relevant inventory items, including underlying concept building blocks of the document’s subject.

Step 2. Determine which items the average intended audience member is well acquainted with and which will require extra care.

BLANK  
CONCEPT  
INVENTORY

Figure 1. Blank Concept Inventory

No	Concept Item	Yes

EXAMPLES

Figure 2. Compound Bow Concept Inventory

No	Concept Item	Yes
	1. General bow construction	
	2. Sight construction	
	3. Arrow rest construction	
	4. Stabilizer construction	
	5. Cam instruction	
	6. Release instruction	
	7. Cam and release working together	
	8. Sight instruction	
	9. Stabilizer instruction	
	10	
	11	
	12	
	13	
	14	
	15	
What principles of operation will be illustrated?		

This concept inventory was supplied by the Compound Bow Project (2008), used in this research. Items 1-5 indicate that the major sub-assemblies of the Compound Bow necessary for the operation of the device, including the sight construction and the stabilizer construction. Items 6-9 indicate the need to understand how some of the subassemblies work alone and in conjunction with one another.

Figure 3. Transfer Case Concept Inventory

No	Concept Item	Yes
	1. Allows for four wheel drive (multiplying power to front and rear axles)	
	2. Can multiply power for greater control	
	3. Chains transfer rotary motion	
	4. Gears can provide rotary inversion	
	5. Unequal gear size produces speed/torque differential	
	6. Disengagement of gears allows for adjustability of power	
	7. A mechanical differential forces same rotary direction of motion with potentially different speeds	
	8. Universal joints allow flexibility in many directions while transferring axial velocity	
	9. Planetary gears allow for multidirectional rotation	
	10. Ribs conserve material and increase strength	
	11. Ball and needle bearings eliminate kinetic friction and thus prolong parts (material wear) and reduce heat (reduce chance of creep)	
	12. Finely finished surfaces reduce friction (gears)	
	13. Springs are used to assist in complex processes	
	14. Material selection allows for broad range of functions	
	15. Four wheel drive means greater grip / climbing ability. Four wheel drive necessary for snow/sand/forest rescue	
<p>What principles of operation will be illustrated?</p> <p>The animation demonstrates how power gets transferred from the engine to the front and rear axles of a four wheel drive vehicle. We intend to show the shifting mechanism and its ability to change from “High” to “Low” gear ratios in order to illustrate the possible multiplication of power for varying purposes. This entails putting the gears into a “Neutral” state where the gears are disengaged in order to smoothly change ratios.</p>		

The Transfer Case concept inventory provides a detailed description of the animation aims. It is clear in the transition from the 15 item inventory to the principles of operation, that the authors consciously tried to pare down the complexity of the device to a manageable amount of information.

AUDIENCE DEMOGRAPHY Research has shown that learning is improved when the intended audience is targeted and the information needs and motivations understood.

*The purpose of an audience assessment is to list a portion of the characteristics that describe your audience in regard to the subject matter. Please note: “targeting your audience” does not mean emphasizing the information most interesting (or entertaining) to your audience. Instead the purpose is to focus on how the intended message goals are best expressed to your chosen audience. [Jensen '05]*

An audience assessment differs from a user-centered analysis in that an audience assessment identifies key attributes important for the document’s success but must then synthesize the differing needs of individual users. For example, when considering the prior knowledge of an expected audience, even when the prior knowledge varies slightly, clever consideration must aid designing the document so that gaps in knowledge are covered without boring those audience members already in the know.

In order to build a sketch of the intended audience, consider addressing the questions listed below.

1. Is your audience homogenous or heterogeneous?  
What are the differences?  
.background education?  
.prior knowledge?  
.professional experience?  
.relevant cultural experience?
2. To what degree do you want/hope/expect your audience to learn from your information? -verbatim retention, non-conceptual retention, conceptual retention, problem-solving transfer?
3. MOTIVATION: Foremost, why is the audience interested in your information?  
What are their goals?
4. POPULATION SIZE: Initially and over time how many people will take in your information in this form?
5. CONTEXT: Where and when will the audience have access to your information?  
Are they familiar with the presentation style and format? Will they be able or wish to revisit material, information?
6. CONTENT: What do you suspect the audience already knows (prior knowledge)?  
What does the audience expect to walk away with? And with how much detail and significance? Give an example of how they will use this information in a new situation.

SYNTHESIS OF CONCEPT INVENTORY AND AUDIENCE ASSESSMENT The synthesis of the concept inventory and the audience assessment is designed to ease the authoring process by pulling out choice bits for use during the design and construction of the technical animations.

To incorporate the results from the audience assessment into the author defined concept inventory, authors are asked to revisit each item of the concept inventory and to determine or to make an explicit educated guess as to whether or not the intended audience is well acquainted with that aspect of the subject’s content. This step should help to refine and inform the document message goals.

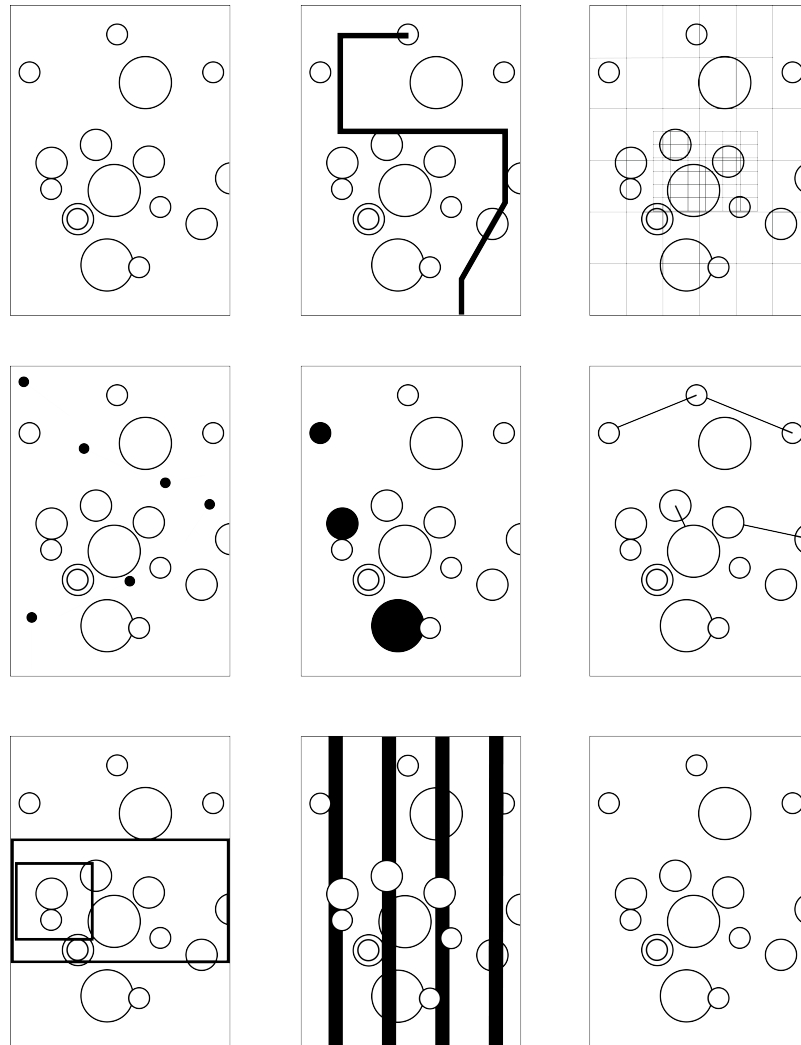
Figure 4. Vacuum Cleaner Concept Inventory

No	Concept Item	Yes
	1. Demonstration of the suction mechanism	x
	2. Dust trap mechanism	x
	3. Dual motors- one powering brush, one for suction	x
	4. Flow of the air in the vacuum	x
	5. Example of domestic use of vacuum	x
	6. Types of material/objects that can be vacuumed	x
	7. Misconception that brush motor does most of the vacuuming	x
	8. Aesthetic design of vacuum	x
	9. Demonstration of how the motor powers the brush	x
	10. Motion of the visor and how it is used	x
	11. Emptying the dust shell where dirt is trapped	x
x	12. Power source of the unit	
x	13. Use of hose attachments (crevice tool)	
x	14. Electrical aspects of motor	
x	15. Electrical aspects of switch	
What principles of operation will be illustrated?		

For example, in the Vacuum Cleaner Project the authors decided to focus the intended project message goals on the: Cleaning of the dust trap, motion of the brush picking up the dirt, the operation of the visor, the mechanism behind the power switch.

Finally, know that the audience assessment process is an iterative one and may result in subtle changes as more information is gathered and feedback from intended audience members is received.

**3.**  
**DESIGN**  
**HEURISTICS**



HEURISTIC 1:. LOGIC MODEL / INFORMATION METAPHOR

HEURISTIC 2:. CONCEPTUAL CHUNKING

HEURISTIC 3:. WAYFINDING & NAVIGATION

HEURISTIC 4:. PRIORITIZATION OF KEY INFORMATION

HEURISTIC 5:. TEMPORAL & SPATIAL RELATIONSHIPS

HEURISTIC 6:. GLOBAL & LOCAL PERSPECTIVES

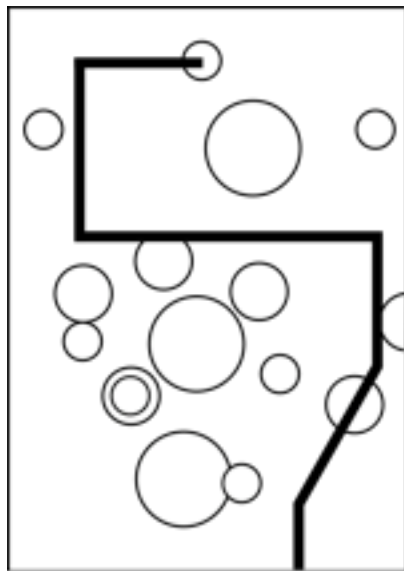
HEURISTIC 7:. COMPLEMENTARY MEDIA

ADDITIONAL DESIGN RESOURCES

Over the course of three iterations of the technical animation information scaffolding intervention, 7 animation specific scaffolding design principles were identified. These 7 principles were whittled down from a longer list of general information scaffolding design principles and codified to be most appropriate for technical animation authors.

Table 1. Scaffolding Principle Citations

Scaffolding Principles	Cited Works
Principle 1. Information Metaphor	Betrancourt, Bisseret and Faure (2001) Levie & Fleming (1993) Dwyer (2006) Lev Kuleshov (1974)
Principle 2. Conceptual Chunking	Levie & Fleming (1993)
Principle 3. Wayfinding & Navigating	Lowe (2003)
Principle 4. Prioritization of Key Information	
Principle 5. Temporal & Spatial Relationships	Parkhurst (1983) Mayer (2003)
Principle 6. Global and Local Perspectives	
Principle 7. Complementary Media	Mayer (2003) Anisworth & VanLabeke (2004) Kolers (1973)



### Principle 1. Information Metaphor

The Information Metaphor Principle is the animation backbone, the logic that takes the viewer from beginning to end, making the necessary key points in between.

Bétrancourt, Bisseret and Faure (2000), found evidence that display strategy was heavily dependent on the “intrinsic properties of the object or situation being displayed” and that this display strategy in turn strongly influenced the information mapping structure to a person’s memory. Bétrancourt, Bisseret and Faure (2000) also suggest: “that these findings can be used to adapt the display strategy to the type of cognitive process or representation that the information system is supposed to teach”. (Bétrancourt, ’00).

The researchers Levie & Fleming also hope that the structure of information and its impact on learning will be taken into account: “A message’s structure

determines how chunks are formed by the viewer and how memory for the message is organized.” Logically organized information will “facilitate flow between short and long term memory” (Fleming, 1993)

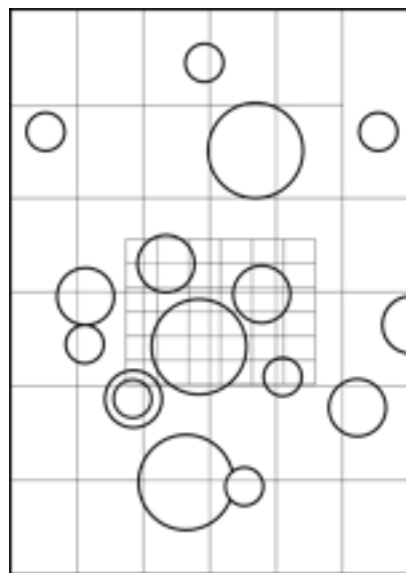
Dwyer found in her 2006 study that the level of required comprehension (from an audience) should potentially influence the structure of information. Dwyer’s stratification was such: higher levels of understanding were difficult for those with low prior knowledge because the nature of animation did not allow time to grasp the necessary underlying factual and conceptual understanding (Dwyer, 2006). Should the audience require an understanding of principles, rules or other types of facts or concepts the type of learning is much different and the design of the information structure should reflect this.

In the early 1900’s, Lev Kuleshov, an early Russian filmmaker believed that juxtaposing two unrelated images could convey a separate meaning. In the Kuleshov experiment he filmed five shots - a famous Russian actor, a bowl of soup, a girl, a teddy bear, and a child’s coffin. He then cut the shot of the actor into the other shot; each time it was the same shot of the actor. Viewers felt that the shots of the actor conveyed different emotions and a different storyline suggested by the order in which the shots were presented (Kuleshov, ’74).

What should be taken from this? The order that information is presented in as a technical animation matters. The order should have a rationale, which even if proved unsuccessful can be consciously modified during future iterations.

Example: The structure of the technical animation will be a function of the subject matter, the message goals and the authors’ creativity. Some examples of how technical animations have been organized include:

- The device’s assembly first and then the device’s operation
- A total disassembly of the device and then the device reassembled to show operation
- Assembly of subassemblies, showing operation after each subassemblies



## Principle 2. Conceptual Chunking/Information Density

The Conceptual Chunking/Information Density Principle describes the breaking up of information appropriately based on audience need, optimizing the cognitive load and then relating ‘chunks’ to each other and to the larger document.

Levie & Fleming tell us: “*Configuration of [information] parts into potentially meaningful units is an important feature of preattentive perceptual organization. The configuration of parts [chunks] into perceptual units takes place when such a configuration permits an ‘emergent property’ to become evident. [Information] chunking is the organization of conceptually related blocks of information. Effective conceptual chunking reflects the optimal amount of related information that can be presented before working memory is overtaxed. The amount of information that can be presented simultaneously increases as ability, maturity, motivation and related prior knowledge increase*” (Fleming, ’93).

Authors can facilitate the comprehension process by appropriately chunking the information into digestible audience-appropriate concepts and by integrating those pieces into the larger organized document representation. The size and arrangement of these conceptual chunks influences the value of the information. Having a grasp of the needs and motivations of the intended audience should inform the chunking of information appropriately.

Figure 5. Disassembled Chainsaw

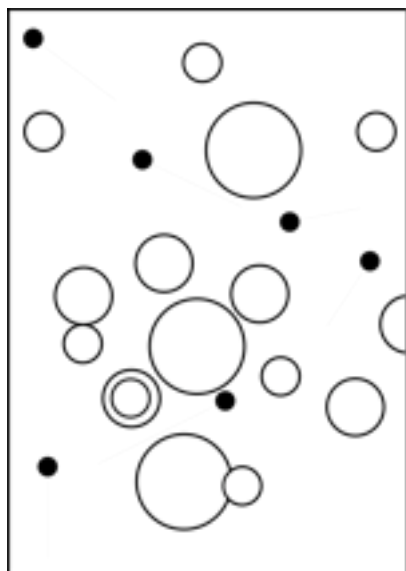


For text-based documents, everyday assumptions based on the college-educated non-expert may suffice. For technical animations however, the ‘chunking’ of information can take on a number of dimensions. A simplified framework of these dimensions might be considered how ‘chunking’ can occur; over the course of the animation (temporal), within the animation’s frame (spatial), as well as along the animation narrative.

The disassembled chainsaw pictured in figure 5, contains over 250 unique parts. The order in which the device is presented will make a large difference in the understanding of the assembly and use of a chainsaw. A chainsaw animation could be ‘chunked’ in many different and effective ways. The actual animation of this device however was not broken up into any subassemblies, nor does the animation, at any point, show much intermediate function. The result was a lengthy animation which showed an impressive rendering of hundreds of parts,

but left the audience with little to no understanding of how a chainsaw works or of its essential components.





### Principle 3. Wayfinding & Navigating

The Wayfinding & Navigating Principle refers to how the author helps the audience negotiate the animation content from beginning to end as well as prevent distraction along the way.

With little use of narration or text, audience members often have a difficult time tracking the ‘thesis’ of an animation project. The wayfinding & navigation principle advocates the use of strategies to help the audience follow the logic of the animation. For example the breadcrumbing principle can now be seen integrated into most websites. In addition, creative design strategies use of *semantic coherence* (a measure of shared understanding between author and audience) is a helpful tool in places where understanding is essential for continued involvement by audience members. Animation projects have recently begun to include embedded titles and references to key mechanical subassemblies.

Lowe (2003) identifies three types of *change events* used in animations:

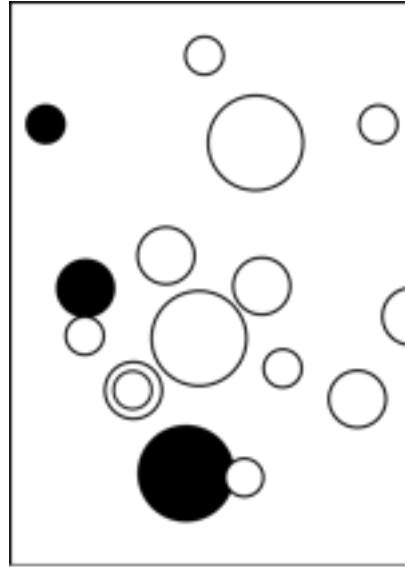
- Transformations, in which the properties of objects such as size, shape and color alter.
- Translations, in which objects move from one location to another.
- Transitions, in which objects disappear or appear.

Figure 6. Scene Title for M1 Rifle



Learners may focus on obvious perceptual events rather than on those that are of most conceptual interest. For example, Lowe found that novices extracting information from a dynamic weather map focused on less important translations rather than the more important but subtle transformations. Effort should be made to guide the audience’s attention through the animation, drawing attention to conceptually important points.

Example: For the animation of the M1 Rifle (figure 6), the authors introduced each scene by framing the beginning of each subassembly with a title.

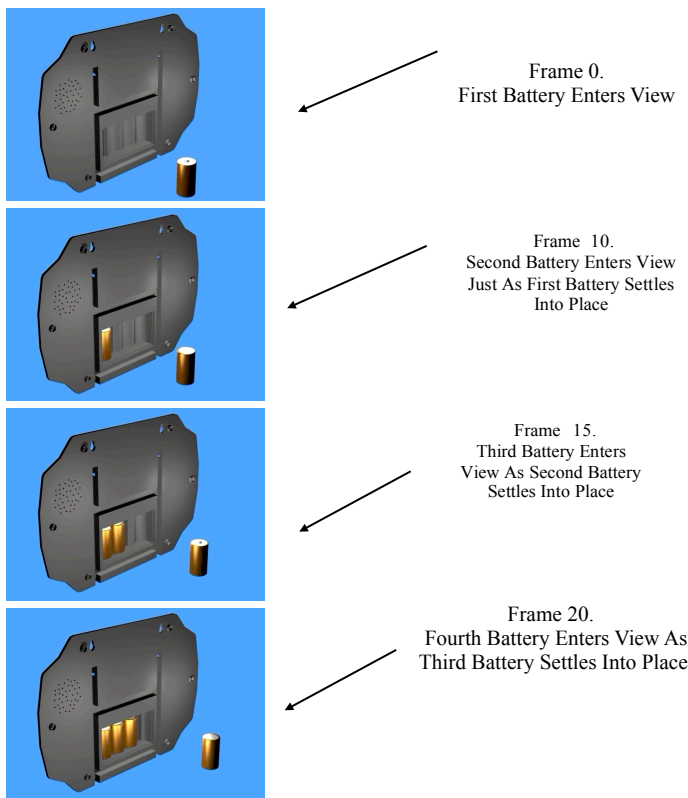


Principle 4.  
Prioritization of Key Information

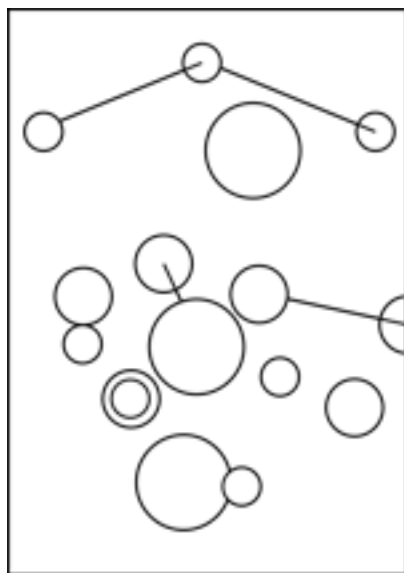
Prioritization of Key Information Principle calls for authors to consciously consider how much information to show, as well as why and when, rather than giving equal weight to all information at all times. This principle rejects giving equal weight to all aspects of the device and instead recommends prioritizing key information elements.

Historically the technical animation projects have given equal weight to practically every screw and washer. While giving equal time to every part and its role in the larger device may seem democratic, it is unfair to the audience. Technical animation projects can contain hundreds of parts, posing an unnecessary cognitive processing burden on audience members by asking them to determine what within the animation is most important while tracking the movement of each part. Without guidance (implicit or explicit), each audience member will self-determine which aspects of the animation they will attend to.

Figure 7. Battery Installation Scene



The device pictured contains four batteries. The animation of the batteries is done in such a way that just as one battery is in place the next has already entered the shot. Over the course of a few moments it is clear that the four batteries are all the same and that all four batteries are necessary for operation. If all of the batteries were to enter at once this information could be potentially glossed over and if equal time were taken adding each battery the viewer may lose patience. The priority of the scene here is that this device is battery operated, and requires 4 batteries to function.



Principle 5.  
Temporal & Spatial Relationships

The Temporal & Spatial Relationships Principle calls for the maintaining of relationships between pieces/chunks of information over time and space.

During the development of a technical animation a 3-dimensional space is represented. With 100's, sometimes 1000's of parts flying in and out of this 3-D space, it is easy to allow the parts to take on a 'life of their own', to move independently of each other. Animation students and surveyed audience members have commented on how difficult it is to focus on the broader animation goals when the relationships between parts are absent. Animations are good at illustrating temporal and spatial dynamics and the implicit relationships between them. The Temporal and Spatial Relationship principle asks that authors explicitly define relationships between parts, subassemblies and the greater whole through use of thematic movement.

Well-defined Temporal & Spatial relationships, used with consistency and leveraged along with animation conventions, allow users to differentiate between the relevant and irrelevant information, and prioritize new or novel information [Parkhurst, 1983]. When it comes to the

tempo of an animation, "the rate at which sequential information is presented should be slow enough to allow accurate perception, attentive scrutiny, elaboration, and comprehension. It should also be rapid enough to prevent attention from wandering." [Mayer, '03]

Figure 8. Air Flow in Paintball Gun



**TIME DESIGN.** Temporal relationships play a large part in comprehension, but excessive slowness causes audience frustration. This is the case because audience members are being asked to hold information in working memory past the level of comfort. Key themes in time design are: *appearance and duration, materialization, manifestation, and presence.*

**SPATIAL RELATIONSHIPS.** In the case of the paintball gun pictured in figure 6, pressurized air follows the arrows indicated in the picture to project a paintball. In this animation, the authors made a clear connection between the pulling of the trigger, to the actuation of the pressurized air, to the firing

of the paintball. The result was not simply an understanding of how all of the parts came together but insight into the cause and effect relationships within the device once the pieces were assembled.

The conscious consideration to temporal and spatial relationships will help to direct audience attention and reduce the cognitive burden.

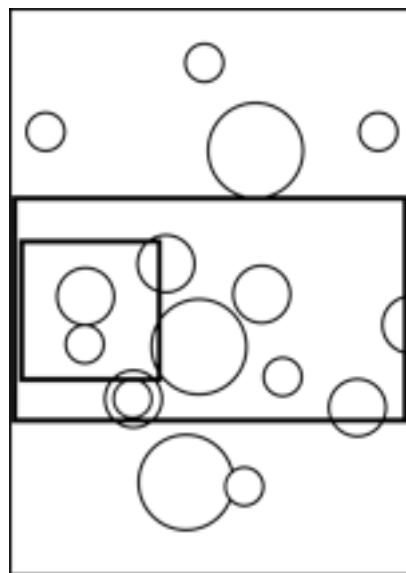
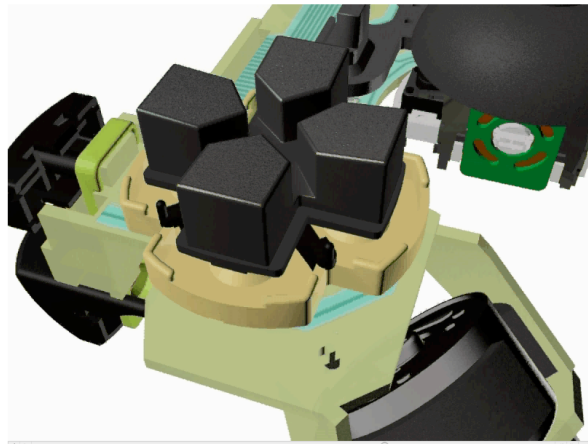


Figure 9. PS2 Controller



#### Principle 6. Global & Local Perspectives

The Global & Local Perspectives Principle asks authors to be conscious when transitioning from the document's big picture to focus on particular aspects or details of the device and back again.

Typically these devices contain parts in a wide variety of sizes. In order to present very small or detailed mechanisms an extreme degree of zoom may be necessary. Unfortunately after even a short duration of time the relationship to the larger device and to the message of the animation may be lost. In a course at UC Berkeley, some animation groups have begun to embed a larger device view into the animation frame.

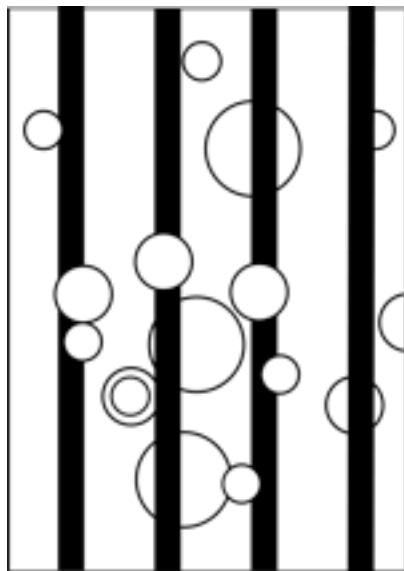
Consider the text equivalent of this challenge. In a successful essay when the time has come to focus more on the details of a research study or to explore the musings of a particular literary work, words/sentences are used to transition from one portion to the next while maintaining the larger essay context. The same must hold for technical animation only new construction devices must be employed.

Another good example of a project that used time and space to tether parts together, to define the relationship between parts was the Playstation 2 Controller Project (2006). For this project the authors adopted a unique movement style and consistently employed the steady motion of each part across a Manhattan angle trajectory. This movement style both tied into the device's theme and provided the audience with a familiar expectation of movement allowing the viewer to accurately predict the placement of parts within the device.

Some groups have begun to embed a global screen within a local screen with explicit pointers in between to aid the audience in locating the current information within the overall 3D space.

Another example of how technical animation projects have maintained both the global and local perspective would be consistently returning to the insertion of the subassembly in to the larger device

In the case of the GoKart animation, the subassemblies were explicitly laid out at the beginning of the animation and each subassembly was systematically added to the GoKart frame/body over the course of the animation. In this example, the authors zoomed in to highlight the unique motion of the cross-shaped button relative to the larger assembly.



### Principle 7. Complementary Media

The Complementary Media Principle asks for the selective use of available animation tools such as sound, camera motion, and lighting to achieve *media coherence*. The availability within any animation program to use lights, motion and sound makes it easy to unnecessarily overuse any one of these tools – resulting in an animation that is overwhelming. The Complementary Media Principle suggests that the use of each of these animation tools be informed by the underlying message goal and the needs of the audience.

Clark & Mayer’s multimedia coherence principle states: People learn better when extraneous words, pictures, and sounds are excluded rather than included. (Clark, 03). However, while some redundancy in communication is actually very important, in order to reduce uncertainty and ambiguity, Ainsworth and VanLabeke write: “When multiple representations

complement each other they do so because they differ either in the information each expresses or in the processes each supports. By combining representations in these ways, it is hoped that learners will benefit from the advantages of each of the individual representations. Multiple representations provide complementary information when a single representation would be insufficient to carry all the information about the domain” (Ainsworth, ’04).

The complementary media principle asks authors to attempt to strike a balance between the minimalist approach advocated by Mayer and the selective redundancy suggested by Ainsworth and VanLabeke, in order to achieve cohesion and concert in the use of the multiple animation attributes. The highly regarded instructional designers, Levie & Fleming warn that, “learning is more correctly attributable to well-orchestrated design strategy than to the inherent superiority of various media.” [Fleming ’03]. If animations are to be transformed into learning objects, it is imperative that the learning needs and style of the audience be addressed. Duke & Pearson (2002) emphasize that in addition to the rudimentary transactional cognitive processing of information, audience members are making judgments (e.g., value, quality, etc.) about the information, bringing unique prior knowledge, and individual thinking and learning techniques to the experience.

DESIGNING  
INFORMATION  
FOR PEOPLE:  
ADDITIONAL  
ADVICE FOR  
TECHNICAL  
ANIMATION  
DESIGN

In addition to the Learning Primer, Audience Assessment and Design Principles presented above, some supplementary concepts may prove helpful when designing technical animations.

Recall that common forms of Cognitive Noise in technical animations are:

- Misalignment of sound and motion
- Unnatural part interaction or motion
- Low resolution of sound
- Pixelated views (high compression)
- Overactive camera motion (shaky, jumpy)
- Low frame rate
- Extreme lighting conditions: too light or dark
- Overly cluttered environment

For complex or detailed information, consider:

**Off-Loading** – moving information to other modalities - text (annotation) or audio (narration or sound cues). Note, the Split Attention Affect is when an audience is asked to both read text and take in visual material at the same time. [Sweller '98, Pollack '02]

**Segmenting** – re-segmenting or re-weighting the animation timeline into bite-sized portions, emphasizing primary or important information.

**Pre-training** – introducing part and component names and characteristics beforehand to familiarize users with building blocks.

If an animation is overwhelming or confusing, consider:

**Weeding** – eliminating unnecessary material, particularly material that however interesting, is unessential.

**Signaling** – providing cues for way-finding or traversing material (narration, sound cues or visual signposts). [Mautone '01]

**Avoid Redundancy** – removing repetition of material that does not play a primary role in the comprehension of an animation's message.

**Synchronizing** – synchronizing or aligning actions to minimize the need for representational holding by audience members.

## 4 Related Prior Research Studies

INTRODUCTION In 2001 Tversky, Morrison, and Betrancourt [Bétrancourt '01, Morrison '01], broadly concluded that more often than not the use of animation had little advantage over static pictures. When advantages were found these benefits were attributed to the animation containing more information than the static version.

Since then, Hoffer and Leutner have reinvestigated this result by conducting a meta-analysis of 26 research studies comparing the use of animation versus static pictures for instruction. Using studies taking place from 1973 to 2003, their research revealed only a medium-sized advantage of animation over static pictures, in scenarios where the represented content was equivalent. This 2007 meta-analysis further attempted to identify which format provides superior learning outcomes under what conditions. [Höffler '07]

With only a medium advantage of animations over static pictures the conclusion is often that generally the use of educational animation doesn't justify the cost.

In the Hoffer and Leutner meta-analysis, the 26 studies were each coded using 11 *metrics*, including *instructional domain*. A total of six *instructional domains* were identified: *Biology*, *Physics*, *Chemistry*, *Mathematics*, *Military*, and *Other* (how to apply a bandage, chess strategies, gun assembly).

These instructional domains are primarily scientific. If we define engineering to be the *application of scientific principles for real-world outcomes*, does the use of technical animation, where other descriptive and depictive methods leave something to be desired, justify the effort? Some animation research has been conducted using various engineering topics for the subject matter. However, most of the articles written on the use of technical animations only describe the context of use, without any qualitative or quantitative analysis. Four technical animation research studies are summarized herein. Two are simply preference surveys and the two additional studies provided more in depth results. What follows is a review of these four studies.

Study 1. Study 1.  
The Planetary Gear Set and Automatic Transmission Simulation for Machine Design Courses.  
The Planetary Gear Set and Automatic Transmission Simulation for Machine Design Courses.  
The survey included the following questions (results were on a 0-4 point scale, 4 being the best (4 = totally agree)).

Q1.The courseware helped me learn about planetary gear systems (score 3.3)  
Q4.The navigation through the courseware was intuitive (score 2.5)  
Q10.Using the courseware increased my interest level in planetary gear systems (score 3.0)  
Q11.I would prefer to use this courseware to learn about planetary gear systems over the text's presentation (score 3.6)

These results give the impression that the mode of communication for learning planetary gear systems appealed to students. Whether or not because this mode was novel or uniquely engaging, it did seem to motivate them, a necessary component when learning at the college level.

Study 2. <i>The Circuitviz: A New Method for Visualizing the Dynamic Behavior of Electric Circuits</i>	Study 2. <i>The Circuitviz: A New Method for Visualizing the Dynamic Behavior of Electric Circuits</i> , study presented a unique interactive method for the representation of circuit design in 3-dimensions. The results were again a simple preference test with 80% of students responding favorably, “They indicated that using <i>Circuitviz</i> imagery helped them to better understand the behavior of dynamic circuits.” [Doering '96]
Study 3. Computer-Aided Education for Magnetostatics	Study 3. <i>Computer-Aided Education for Magnetostatics</i> , presents in real-time, “a computer-aided education (CAE) package allowing [users] to visualize the magnetostatic field in and around the magnetic circuit of a double-U shaped contactor” [Buret '99]
Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	Study 4. <i>Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems</i> [Heragu '03]. The researchers in this case specifically designed the pilot study to question which aspects of the multimedia system were most helpful to students.
Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	The pilot studies address 10 principles of materials handling systems and separately the “design and analysis on integrated materials handling systems”, with a total of 102 students participating.
Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	Using a 5-point rating scale, participants rated the use of real-world examples (4.60) just over the use of visual representations (4.25) including animations. These both rated more highly than ‘stories contrasting appropriate and inappropriate applications of the principles’ (4.03).
Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	When asked in more detail about the different uses of media representations, the researchers distinguish the learning resource using 4 phases – the discover layer, the explore layer, the contrast layer and the extend layer:
Study 4. Applying Cognition and Learning Principles in Multimedia Tools Development: Materials Handling Systems	<ul style="list-style-type: none"> <li>- <i>The Discover Layer frames the principle by showing it in action in the context of a warehouse.</i></li> <li>- <i>The Explore Layer identifies the components or "key aspects" of the principle elaborating each component with examples.</i></li> </ul>



- *The Contrast Layer focuses on applying the principle in real settings.*
- *The Extend Layer prompts users to think about the principle in a different context.*

Twenty-eight participants were asked for their representation preferences. For the *Explore Layer* animation/video was the preferred representation (89%). During the *Contrast Layer* the use of pictures/charts (61%) was on par with animation/video (59%). Finally during the *Extend Layer*, animation/video was again the preferred method (68%). In all 4 phases the use of animation appears valuable.

#### CONCLUSIONS

It may be that research studies with scientific results are soon to come. It is clear that structured research studies in this area are still needed. However, without a reproducible framework for the construction and discussion of technical animations, with explicit message goals, for educational purposes or otherwise, it is unlikely that the results of such studies can be extrapolated beyond one or two cases.

Having reviewed the four studies it is clear that in depth analysis of the structure and impact of technical animations or other dynamic media is needed. It is the intent of this research to provide technical animation construction recommendations based on the results of the collected data and to provide a reproducible framework through which technical animations can be evaluated.

Next, the second portion of this dissertation presents the Information Scaffolding: Technical Animation Research Study, including the study structure, gathered data and resulting analysis. This research uses a Design-Based Research approach which is designed for the collection and evaluation of data in complex settings.

The Information Scaffolding: Technical Animation Research Study looks at technical animations from multiple viewpoints. In this study the technical animations are reviewed from the perspective of three different audiences, the authors' construction processes are evaluated and the completed projects are critiqued using a cinematographic content analysis. This host of evaluation methods is used in an attempt to answer the difficult question: in what ways are technical animations effective?

# part 2

## technical animation

### research study

5 research study experimental design

6 scaffolded authoring, information scaffolding design implementation

7 quantitative and qualitative assessment of audience perception & comprehension

8 content analysis

## 5 Research Study Experimental Design

**INTRODUCTION** This chapter presents the framework for the Information Scaffolding: Technical Animation Research Study. This study follows a design-based research methodology and leverages both quantitative and qualitative research methods. The center of the Information Scaffolding research study is a set of 19 technical animations, the “authors” of which are small groups of senior-level mechanical engineering students. The results in this dissertation come from the Spring 2008 Information Scaffolding Intervention, after two years of trial iterations which took place in Spring 2006 and Spring 2007. The data collected consists of the technical animations themselves (4-10 minutes in length), the written project supplement that each group submitted along with the project, an extensive peer evaluation (fellow participant review 2008), as well as two intended audience surveys. The methods for the evaluation of this data are outlined in more detail at the end of this chapter.

**DESIGN-BASED RESEARCH** To begin, the structure of this research study is framed using a Design-Based Research approach. Design-Based Research (DBR) is a method of research developed to collect and study research phenomena in context. Originally used in the field of education, DBR allows for the study of individual and group learning in context. Because many of the DBR methods proved useful in studying these complicated scenarios, DBR is now being used to study learning outside of the field of educational research. This method structures the Information Scaffolding: Technical Animation Research Study in order to investigate the role of the Information Scaffolding in aiding non-expert information designers to supplement the design of documents for improved comprehension in context. Context in this case being the authoring and information design that needs to occur within the framework of the audience goals and the author’s existing design process.

From Collins 1994, *Design research was developed to address several issues central to the study of learning, including the following:*

- *The need to derive research findings from formative evaluation.*
- *Difficulties arising from the complexity of real-world situations.*
- *Relief from the unrealistic constraint of experimental control.*
- *Large amounts of data arising from a need to combine ethnographic and quantitative analysis.*
- *Acknowledgement of the multiple approaches or designed solutions for a given problem.*

[Collins ‘94]

Specifically, the Design-Based Research method is used here to investigate the role of the three-pillared Information Scaffolding framework in the creation of technical animations for improved user-comprehension. In other words, can authors leverage the underlying conceptual building blocks of the document’s subject, the information gained about an intended audience (prior knowledge, information needs, etc.) and technical animation design principles to ‘scaffold’ (structure, organize and present) a technical animation for improved comprehension.

**REPORTING DESIGN-BASED RESEARCH** Again from Design-Based Research from Collins, 1994  
*The experimental literature developed a conventional structure for reporting on experiments that evolved over time. The structure consisted of four parts: Background to the problem, experimental method, results, and discussion. Because design research re-conceived the experimental process, there needs to evolve a different structure for reporting. Tentatively, we propose that there should be five sections in reporting on design experiments:*

**Table 2. Principles for Reporting Design-based Research**

<b>1. Goals and elements of the design.</b>	<i>An important aspect of reporting on design experiments is to identify the critical elements of the design and how they fit together to accomplish the goals of the design. The critical elements of a design may be the materials, the activities, a set of principles, or some combination of all these. It is equally important to describe the goals of the design and how all the elements are meant to work together to attain those goals. Goals, critical elements, and their interactions need to be described in enough detail, so that it is possible to evaluate how well the design was implemented in different settings.</i>
<b>2. Settings where implemented.</b>	<i>The description of the settings needs to include all the information relevant to the success of the design outlined in the characterizing in dependent variables' section. Differences between how the design was implemented in each setting should be detailed, so that readers can evaluate how faithfully the design was carried out in each setting.</i>
<b>3. Description of each phase.</b>	<i>The design is likely to go through a different evolution in each setting, so it is necessary to describe each phase in each setting. When changes are made in a setting, the reasons for the changes should be specified along with the effects of making the changes. It also makes sense to describe how the critical elements of the redesign accomplish the goals of the original design or how the goals have changed.</i>
<b>4. Outcomes found.</b>	<i>The outcomes should be reported in terms of a profile of values on the dependent variables in the different settings, much like qualitative and quantitative data are reported about different products in Consumer Reports. To the degree intermediate data were collected describing the different phases, these should be included.</i>
<b>5. Lessons learned</b>	<i>Considering what happened in the different implementations, the report should attempt to pull together all the findings into a coherent picture of how the design evolved in the different settings. It is important to describe the limitations and failings of the design, as well as the successes, both in implementation and outcomes.</i>

RESEARCH  
HYPOTHESIS

The use of DBR allows for the study of a handful of well-identified Information Scaffolding research questions, while allowing their study to take place in a realistic context, including the capture of subtle, yet important detail and nuance. How and under what circumstances does the Information Scaffolding approach aid in the construction of technical animations? The evaluation of the Information Scaffolding methods as a simple author-directed, user-centered approach to improved 'understanding', begins in this dissertation by looking at the resulting technical animation process and products from three perspectives:

1. Author Scaffolding. Scaffolded Design Implementation: How do the authors implement the Information Scaffolding Framework? This is covered in Chapter 6.
2. End Users/Intended Audience - Audience Perceptions & Comprehension. What are the perceptions and the degree of comprehension of the animations by audience members? This is initially evaluated in Chapter 7.

3. Content Analysis: What characterizes the content of the finished product? This is covered in Chapter 8.

RESEARCH TESTBED: Senior Mechanical Engineers Construct Technical Animations in groups spring 2006, 2007, & 2008.

Undergraduate engineering students (primarily mechanical) at the University of California at Berkeley, in three person teams, design and produce 5-10 minute technical animations illustrating the assembly and operation of moderately complex mechanical devices. This course is titled E128 – Advanced Engineering Graphical Communication. As an addition to the existing pedagogy of this course the Information Scaffolding methodology supplemented the course during the spring 2006, 2007 & 2008 semesters.

Each spring, the students must create an animation of the assembly and operation of a moderately complex mechanical device, composed of several mechanical parts, and rendered using varying material finishes. Additionally, the completed animation projects were to illustrate the aspects of the device’s operation that are difficult to visualize or understand conceptually (airflow, magnetic field, fluid flow, microscopic material properties, etc.).

Each project received a final grade based on the use of purposeful creativity and the effective use of:

- Solid and surface modeling.
- Rendering techniques to emphasize depth and dimension.
- Colors and surface properties to represent materials and surface qualities.
- Lighting to present the device and to highlight key features.
- Animation to present the assembly and operation of the device.
- Effective presentation of visually and conceptually difficult aspects of the device.
- Camera motion to view the device from different viewpoints.
- Soundtrack and music.

Before the introduction of the Information Scaffolding methodology, the technical animation projects successfully met all of the technical grading requirements but each year many of the groups failed to produce a cogent and compelling animation that successfully provided consistent information takeaways and transferable learning.

During this research study, the students acting as technical animation authors were questioned regarding their animation message goals and about their intended audience. In groups, the students discussed approaches to designing and presenting the selected subject matter to the project’s target audience. At the end of the semester students presented completed animations to the class and the class evaluated each animation using a standardized evaluation form.

EXPERIMENTAL DESIGN & DATA EVALUATION

The Information Scaffolding methodology was piloted during the spring 2006 and 2007 semesters. The significance of the spring 2006 semester to this research study was an initial validation of the Information Scaffolding three-phase intervention structure and the identification of animation specific scaffolding methods. While the three-phase intervention structure proved successful (as a positive complement to the existing course without over-burdening the students), the content of the 2006 intervention proved too abstract to translate to the concrete analysis of completed animation projects.

The data collected from the spring 2008 Information Scaffolding intervention is evaluated from three perspectives, in order to capture the Information Scaffolding approach from the key stakeholder points of view. The evaluation begins by looking at the unique application of the IS methods by the authors of the technical animations. Next, audience perceptions and comprehension are examined. Finally, the finished animation projects are reviewed by technical animation experts.

Chapter 6. Takes a close look at the preparatory information scaffolding approaches taken by the authors of the technical animation projects. This chapter evaluates the data in the order of the information scaffolding process: the development of a concept inventory, preparation of an audience demography, the synthesis of the two preceding steps, the selection of the document message goals and finally the use of technical animation specific design scaffolding principles informed by the information developed throughout the scaffolding process. The results of the *fellow participant review 2008* are also evaluated in this chapter as this end of the semester review represents a peer-evaluation of the scaffolding of each animation project.

Chapter 7. Looks at the complete technical animation projects from the perspective of two audiences. First, a small set of intended audience members - education non-experts in the author identified disciplines. This survey provides qualitative feedback on the technical animation projects. The second audience is a heterogenous set of technically minded students. This critique looks at how, as a method and approach, Information Scaffolding is effective at transforming documents from being author-centered to audience-centered. The students viewed five animations, two of which were well scaffolded, one of which was poorly scaffolded and two of which were well constructed but whose authors did not receive the information scaffolding intervention.

Chapter 8. Recall that the Information Scaffolding method was designed for ease of use by “everyday” authors who are not experts in the area of information design. Having inspected the process by which the intervention authors (“everyday” authors) constructed the 2008 technical animations, a review by technical animation construction experts was conducted to evaluate the audience-centeredness of the projects and to inform the discoveries made in Chapter 6 and 7.

Table 3. Technical Animation Study Experimental Design

Information Scaffolding : Technical Animation	Iteration	Experimental Design	
Year	Revision	Experiment	Data Collected
2006	Trial Iteration 1 <i>revised emphasis of intervention</i>	2 day intervention 60 minute group meetings	interviews written project supplement
2007	Trial Iteration 2 <i>revised emphasis of intervention</i>  <i>revised scaffolding principles</i>	2 day intervention 30 minute group meetings	interviews written project supplement
2008	Final Testing Iteration <i>emphasis on comprehension and audience assessment</i>	2 day intervention 30 minute group meetings	interviews written project supplement
2009	No Revision	Intended Audience Survey	9 educated non-experts view and evaluate 2008 technical animations
2010	No Revision	2008 Study Evaluation	56 intended audience animation critiques

ITERATIVE DEVELOPMENT CHANGES Methodological revisions from 2006 (spring) to 2007 (spring) include:

- A change in emphasis during the course lectures from communication & motivation to an audience-centered design approach.
- The changes from 60-minute working meetings to 30-minutes.
- Clarification of the seven animation specific scaffolding design principles.
- An added requirement of a written supplement and three comprehension questions.

The changes from 2006 to 2007 were successful in streamlining the information scaffolding intervention. The 2007 study then showed that the areas of audience assessment and intended message goals were underdeveloped – lacking techniques for evaluation. In response to the results of the 2007 scaffolding study, an emphasis was put on the *intended audience* and *audience assessment* aspects of scaffolding.

Methodological Revisions from 2007 to 2008: New for the spring 2008 study, the animation groups were given a choice of four intended audiences: *Electrical Engineers, Material Scientists, Industrial Designers, and Business Decision Makers*. The assumption given to the class was that an audience member from one of these groups had both an undergraduate degree in this area and had worked in this field. As part of the written project supplement the groups were asked to:

1<sup>st</sup>: develop 15 items constituting a concept inventory. [Each group was given special instruction on this during the 30 minute group meeting]. The 15 items of the concept inventory were to be developed using the definition: ***A concept inventory is a list of items including: principles of operation, background information, cultural relevance, and common misconceptions.*** This definition came with the note that these concept inventories would not be complete, that 15 items were not enough to sufficiently cover any given subject. The groups, however, needed to take a preliminary stab at the concepts they thought constituted the subject of their mechanical device. The concept inventory exercise had the additional value in helping the groups describe the concepts involved in their mechanical device, thereby putting (externalizing) their assumptions on the table and helping the group members get onto the same page.

2<sup>nd</sup>: after the group had constructed the concept inventory and identified the project's intended audience, the groups were asked to indicate which of the 15 items they were assuming their intended audience already knew and were familiar with [indicated with a Yes or No].

3<sup>rd</sup>. the groups were to decide, based on the knowledge prescribed by the authors to the intended audience and in conjunction with the project's message goals, where the emphasis and priority would be placed in the design and construction of the technical animation.



# 6 Scaffolded Authoring

## Information Scaffolding Design Implementation

**INTRODUCTION** The analysis of the authors' scaffolding begins in this chapter by evaluating the written project supplements. This order begins with the device concept inventory, followed by the audience assessment, synthesis of concept inventory and audience assessment, review of comprehension questions and finally the application of the 7 Information Scaffolding Design Heuristics. The second portion of this chapter uses the results of the peer assessment (*fellow participant review 2008*) to quantitatively evaluate Information Scaffolding's impact on the completed technical animations.

Recall that Information Scaffolding is meant to be a simple preparatory process for the average or "everyday" author, to aid in the construction of audience-centered documents. The participants in the 2008 Information Scaffolding intervention for Technical Animation were coached through a series of scaffolding steps before and during the construction of the technical animation projects.

In *Phase 1* of the Information Scaffolding intervention, the participants were introduced to the generalized concepts of Information Scaffolding. The second phase was designed to address the unique design challenges of each animation project.

*Phase 2* of the scaffolding intervention consisted of 30-60 minute working meetings attended by an information scaffolding facilitator and all project authors. The purpose of these meetings was to discuss the target audience(s), intended message goals, & applicable animation scaffolding design principles. Additionally, these working meetings attempted to get the project teams onto the "same page" in terms of efficiently moving the project ahead.

In between these working meetings and the *Phase 3. Final Critique (fellow participant review 2008)*, the groups were required to complete a written supplement including; *the project's intended audience, the animation's primary and secondary message goals* and the *scaffolding design principles* used to articulate the project message goals to the selected audience. Beginning in 2007 the groups were also asked to include three project related comprehension questions, which they as authors believed an intended audience member would be able to answer after watching the technical animation project. These questions were to be closely tied to the project's primary message goals.

In *Phase 3* the participants in the Information Scaffolding intervention acted as peer reviewers by answering scaffolding-based survey questions along with the three author provided comprehension questions after viewing each technical animation.

CONCEPT INVENTORY The scaffolding worksheet contains four essays and begins by asking for a 15-item concept inventory.

*The purpose of a concept inventory is to articulate a set of individual concepts that together describe the knowledge and information “contained” by the document you will construct. A concept inventory is a list of items including but not limited to key information, related learning principles and background, cultural relevance, and common misconceptions. The purpose of this exercise is to gain a detailed understanding of the necessary knowledge contained within and in support of your message goals. Your concept inventory will not be complete in the sense that will cover everything, instead it will be a brief synopsis of the concept, as you understand it.*

The full information scaffolding worksheet can be found in Appendix 1 an example concept inventory is found in Figure 10. Vacuum Concept Inventory.

The completed concept inventories contained 4 -15 items and had a range of inventory items as

Figure 10. Vacuum Concept Inventory

NO	Concept Inventory:	YES
	1. Demonstration of the suction mechanism	X
	2. Dust trap mechanism	X
	3. Dual motors- one powering brush, one for suction	X
	4. Flow of the air in the vacuum	X
	5. Example of domestic use of vacuum	X
	6. Types of material/objects that can be vacuumed	X
	7. Misconception that brush motor does most of the vacuuming	X
	8. Aesthetic design of vacuum	X
	9. Demonstration of how the motor powers the brush	X
	10. Motion of the visor and how it is used	X
	11. Emptying the dust shell where dirt is trapped	X
X	12. Power source of the unit	
X	13. Use of hose attachments (crevice tool)	
X	14. Electrical aspects of motor	
X	15. Electrical aspects of switch	

vague as: *principles of operation and use of device (Garden Blower)* to incredible specific as in: *shell in aerodynamic to decrease drag (RC Helicopter)*.

AUDIENCE  
DEMOGRAPHY

The second step of the scaffolding process was for the groups to take a first stab at an audience demography. The purpose of the Information Scaffolding *audience demography* is to bring an initial shape to an audience which isn't fully defined, comprised of differing individuals and changing with time, beginning with a list of some of the characteristics that describe your audience. *Please Note: by targeting your audience this does not mean emphasizing the information most interesting to your audience but instead focusing on how the principles of operation are best expressed to your chosen audience.* The portion of the worksheet used to guide the audience assessment is presented below in Figure 11. This worksheet supplemented and came after the group conversation about audience with the scaffolding facilitator.

Figure 11. Intended Audience Worksheet

<p>Target/Intended Audience(s). The purpose is to list some of the characteristics that describe your audience. Please Note: by targeting your audience this does not mean emphasizing the information most interesting to your audience but instead focusing on how the principles of operation are best expressed to your chosen audience. College educated:</p> <p>Electrical Engineers      Material Scientists Industrial Designers      Business Decision Makers</p>	
<p>Who is your target audience? Is your audience homogenous or heterogeneous in; .background education? .prior knowledge? .Professional experience? .relevant cultural experience?</p>	
<p><b>POPULATION SIZE</b> Initially and over time how many people will watch your animation?</p>	
<p><b>MOTIVATION</b> Foremost, why is the audience interested in your document? What are their goals?</p>	
<p><b>CONTEXT</b> Where and when will the audience have access to your animation? Will they be able to view the animation only once or repeatedly? Will they be able to pause or will they be watching the animation straight through? Are they familiar with the presentation style and format?</p>	
<p><b>CONTENT</b> What do you suspect the audience already knows? What does the audience expect to walk away with? And with how much detail and significance? Give an example of how they will use this information in a new situation.</p>	

For the spring 2008 intervention, animation authors were asked to select from four potential audiences, all of which were different from mechanical engineering but still likely to be exposed to technical animation. Authors were to assume all of these audiences were intelligent college educated experts in non-mechanical engineering fields.

The intended audience choices were:

Electrical Engineers [EE]  
 Material Scientists [MS]  
 Business Decision Makers [BDM]  
 Industrial Designers [ID]

All 19 projects identified an intended audience and attempted, to varying degrees, to let this intended audience inform the design of the technical animation project. *OTHER* was not given as an intended audience option. Five projects however chose to address audiences other than the four listed above. Of these five projects, two projects identified general audiences and three identified specific audiences different than the four above. The three specific audiences were ‘enthusiasts’ of the depicted device, for the Batmobile –Batman enthusiasts; for the Fishing Reel – fishing enthusiasts; and for the Compound Bow – archery enthusiasts.

The audience assessment portion of the Information Scaffolding Intervention is summarized in the written project supplement provided by the project authors. The brief assessment happened in two phases. The first portion of the written project scaffolding supplement was designed to help the project authors develop a brief but broad description of the intended audience.

The attempt to address the intended audience begins to break down at this phase. For individual projects, although most assumed a heterogeneous audience, there was little-to-no indication of what that means. For example students could have specified at least 2 –3 varying attributes within a specified audience, but there was no evidence of this in the written supplements.

From the written project supplements, it is clear that most projects would ideally like the intended audience to both pause and replay the animation. The Electric Drill project supplement is representative of the scenarios in which most authors envisioned the finished project being used.

Figure 12. Electric Drill Audience Viewing Scenario

- *Anywhere and anytime since the animation will be available online*
- *The audience may repeat the animation to pick up on greater detail and complexity.*
- *The audience will be able to pause the animation whenever they want, but it should be watched through so as not to break the stream of knowledge presentation.*
- *The audience already knows the use of the drill (drilling and screwing)*
- *The audience will learn about the powering mechanism of the drill.*
- *The audience might be able to apply the principles of operation of the drill to other machines they encounter (or inventions).*

Reviewing the written project supplements showed that most groups were very good at imagining an ideal scenario that they would have liked the intended audience to view and have access to the finish technical animation – many of these scenarios were both unrealistic/unlikely and not specific enough.

The authors both satisfied the assignment and attempted to answer the audience related questions as requested. The intention of the assignment was that they would have used the opportunity to couch the animation in more realistic scenarios. It is difficult to define a realistic scenario and perhaps once a more realistic scenario presents itself the authors may have an easier time at ‘scaffolding’ or designing for the scenario and to meet the user needs.

CONCEPT  
INVENTORY  
AND AUDIENCE  
ASSESSMENT  
SYNTHESIS

The second phase of the audience assessment was to revisit the author-defined concept inventory, evaluating which of the items are assumed to be well known by the intended audience. This is to be the synthesis of the concept inventory and the audience assessment - and should be the basis for defining the project message goals.

Only six of the 19 projects included this secondary step of mapping the audience demography to the concept inventory. The six projects that completed this step were: Floppy Drive, Fishing Reel, Electric Drill, Breadmaker, Vacuum, Playstation 2. Of these projects three assumed that the intended audience knew all items in the concept inventory, to some degree defeating the point. Below are examples from the second phase of the audience assessment – Concept Inventory & Audience Assessment Synthesis.

The Electric Drill Project (audience: general), selected *yes* for 10 of the 11 items with the exception of #11 written as – *common misconceptions*. The authors did not specify what these common misconceptions were.

yes	Concept Inventory	no
	Common Misconceptions	√

The Fishing Reel project (general audience) had an 8 item concept inventory, all checked yes with the exception of # 7, *Feature – clicking noises when line winds/unwinds*. This feature was addressed to some degree with the project’s second animation question.

yes	Concept Inventory	no
	Feature – clicking noises when line winds/unwinds.	√

The Floppy Drive Project (audience electrical engineers) had a 13 - item concept inventory. This item was not directly addressed in the comprehension questions:

yes	Concept Inventory	no
	Two layers of fabric inside the disk (to reduce friction)	√

The Vacuum Cleaner exemplar shown in figure 10 did an excellent job of articulating to themselves the aspects of the device they assumed the intended audience would not know. The authors went on to address broader message goals with the animation but it is clear in viewing the animation that they had taken the perspective of the potential audience into account.

COMPREHENSION As part of the 2008 Animation Project Supplement, each project group was asked to provide three written questions (comprehension questions) derived from the analysis of the concept inventory and based on the intended audience information need. These questions are in theory based on the intended message goals and the answers are contained within the animation project.

During the final project critique (*Fellow participant review 2008*), students enrolled in the E128 course were to attempt to answer three project related questions, acting in their role as peer-reviewers. While these students were not necessarily members of the projects' intended audience, this population of primarily senior mechanical engineering students was uniquely primed to answer these questions, both because of their mechanical engineering education (the primary subject matter of each animation project) and for having been participants in the information scaffolding intervention, giving them a full understanding of each question's context.

Below are three examples of questions that accompanied the completed projects.

Floppy Drive Project - *How does the device read/write by magnetism?* The challenge to audiences here is two-fold, foremost, the question is very broad with no indication to what depth of detail would qualify as a correct response. Secondly, an answer, even a cursory one is not contained within the animation. The incorrect or absent responses by audiences could be because of either of these reasons.

Camera Lens Project - *What are the 'stops' in a camera lens?* This also had the problem of poorly presented or absent content in the animation. Also vocabulary presents an issue here, since the term 'stops' was not introduced to the audience until the comprehension questions are presented.

Momo Force Feedback Wheel Project - *How is it put together?* The same issue of being too vague as in the Floppy Drive project. What aspects of assembly are the authors asking about? and What level of detail will be acceptable?

The comprehension questions were meant to help the authors translate their intended message goals into concrete and salient objectives. For the 2008 intervention, 18 of the 19 groups did not provide responses they would deem 'acceptable' question responses, it is thus impossible to determine how many completely correct answers were provided. Acting as evaluator, I coded and binned the submitted responses as correct (even partially) and incorrect.

An example of a partially correct response is:

RC Helicopter:

Question: How does the swash plate movement affect rotor tilts?

Answer: tilts to change left/right direction.

Examples of an incorrect response are:

Floppy Disk Drive:

Question: How does the device read/write by magnetism?

Answer 1: by spinning the disk

Answer 2: light goes "pew" and writes

Answer 3: to be honest, the animation did not put enough focus for me to get it

Answer 4: don't know

Answer 5: by spinning the disk

Once coded, the 2008 critique responses to the 3 questions were categorized into 5 bins.

- 0 - essentially no correct answers
- 25 - few correct answers (~25%)
- 50 - approximately (~50%) correct answers

- 75 - ~75% correct answers
- 100 – all questions at least partially correct

A synopsis of results from 19 animation projects:

- 15 groups received 100% on at least 1 question
- 6 groups received at least 100% on 2 questions
- 3 groups had 100% responses to all 3 questions
  - o Leaf Blower, Folding Bicycle, Boat Motor
- The 3 lowest average scoring projects were
  - o Floppy Drive, Beer Launching Fridge, RC Helicopter
- 3 groups received 0% on a single question
  - o Floppy Drive, Camera Lens, Force Feedback Wheel

The comprehension scores show a need for authors to attempt to answer their own comprehension questions - a step which in fact may help to clarify the presentation of the message goals. The issue of comprehension is also muddled in that the authors are responsible for writing the comprehension questions. The failure of audiences to answer some questions may be the result of any combination of three issues: 1. The question may be poorly written in that the authors are asking for a simply written or multiple choice type response or that the question is far too broad or abstract for an audience member to tackle. 2. The material necessary to answer the question may not in fact be contained within the animation. 3. the use of vocabulary and terminology is inconsistent between the animation and the written questions.

SCAFFOLDING DESIGN PRINCIPLES Seven animation specific scaffolding principles were presented to the project authors, the uses of which the authors wrote about in the written project supplements. The technical animation scaffolding principles for the spring 2008 semester were:

1. Information Metaphor
2. Conceptual Chunking/Information Density
3. Wayfinding & Navigating
4. Prioritization of Key Information
5. Temporal & Spatial Relationships
6. Global and Local Perspectives
7. Complementary Media

SCAFFOLDING PRINCIPLES To give a sense of the scaffolding narrative supplied by the animation project authors short excerpts are included below:

EXEMPLARS

**FOLDING BIKE:** *We will show the assembly of the bike in its entirety. Certain sub-assemblies will be put together in their own section and then put on the main assembly of the bike. We will maintain audience attention through the use of music and interesting camera angles that allow the viewer to see every aspect of the bicycle assembly. We will place more emphasis on important aspects for the overall functioning of the bike, like how the hinges work, and place less emphasis on things like the reflector.*

**BATMOBILE:** *We began the animation by justifying the need for our animation through a Batman comic. While Batman is keeping watch over Gotham City, he realizes he needs a new vehicle to help him fight crime. Then our animation transitions into the technical aspects of the Batmobile. We used conceptual chunking and prioritization of key information by focusing on several key technical aspects of the Batmobile, such as the turbine, suspension, steering and gun elevator. A normal car has thousands of components, and a futuristic car such as the Batmobile would have even more. However due to the limitations of time and labor, we decide to narrow down our scope down to the bare-bone function and excluded many components. Throughout the animation we used music to complement the motion of the objects in the scenes. At certain times, the music is lower and mellow to allow the audience to focus on the technical assembly, other times the music is heightened and intense to stir an emotional response.*

**FISHING REEL:** *We divided the demonstration of features of the reel into chunks, isolating that aspect by vanishing irrelevant parts. That said, the parts were always preserved in their relative position - we never partially disassembled the reel and showed operation out of context. We did not include the irrelevant feature of the winding/unwinding noisemaker, since it does not figure into the operation of the reel. We added spotlights on important parts of the animation to help call attention to them and make details easier to see, and showed overall operation before going into specific features for advanced users, concluding with a context animation showing the reel "in action." We avoided going into too much detail in maps and textures to avoid distracting the viewer from the features that we were trying to demonstrate. We did not present information by metaphor, always showing the reel in a literal operational state.*

**DIGITAL CAMERA:** *In creating our animation we tried to find a way to best articulate the assembly of a digital SLR (single-lens reflex) camera focusing more on the mechanical movement of the components of the camera as opposed to the electrical (which obviously play a large role in the camera's operation and function). We felt that for our specific audience it would be most advantageous for us to show more of the mechanics since we assumed that, in general, most of them would already have some prior knowledge regarding the circuitry and electronic features of a digital camera (or DSLR). We hope that this will help to illustrate and convey to our audience a better sense of how a DSLR functions as a mechanical device as opposed to a digital one.*



The use of the animation specific scaffolding design principles by all projects were tallied - and summarized in the table below.

Table 4. Author Indicated Scaffolding Principles

	Information Metaphor	Conceptual Chunking/ Information Density	Wayfinding & Navigating	Prioritization of Key Information	Temporal & Spatial Relationships	Global and Local Perspectives	Complementary Media	Principle Count
DVD BURNER	X	X	X	X	X	X		6
FLOPPY DRIVE		X					X	2
LEAF BLOWER	X		X	X	X	X	X	6
FOLDING BIKE	X		X	X	X	X	X	6
BATMOBILE		X		X			X	3
FISHING REEL		X	X	X	X	X	X	6
MAGIC BULLET	X	X				X		3
COMPOUND BOW	X							1
ELECTRIC DRILL	X		X	X	X	X	X	6
TRANSFER CASE	X	X						2
CAMERA LENS	X	X	X	X	X	X	X	7
BREADMAKER	X				X	X	X	4
CANON DSLR	X	X	X	X	X	X	X	7
BEER LAUNCHING FRIDGE	X	X	X	X		X	X	6
VACUUM			X	X	X	X		4
RC HELICOPTER	X		X	X	X	X	X	6
PLAYSTATION 2			X	X		X	X	4
FORCE FEEDBACK WHEEL		X	X	X	X		X	5
BOAT MOTOR			X		X		X	3
totals	10	9	13	13	11	12	13	

Two groups attempted to address all 7 scaffolding principles while other groups attempted to address some of the principles. These two projects, the Camera Lens and the Digital Camera both received high final grades and high scaffolding principle averages, however there were also projects that did not attempt to address all 7 principles and still scored highly. On average, the 19 projects attempted to address 4 or 5 scaffolding principles out of 7 (average 4.58). Using the lens of the fellow author comprehension scores (see Chapter 6 - audience perceptions), the top, bottom and mixed scoring projects were reviewed.

CHARACTERIZATION OF A SELECTION OF PROJECTS	To conclude this qualitative analysis the scaffolding of six of the 19 projects are reviewed. These projects are reviewed overall for their unique scaffolding implementations.  Boat Motor Project.
---	--

*Boat Motor Questions*

1. *How is the propeller driven?*
2. *Is this boat motor run off of gasoline or batteries?*
3. *Does this motor need to be pull started, or does it have an electric starter?*

Analysis:

The boat project had comprehension questions which were very basic, almost trivial and questions 2 and 3 are simple multiple choice— however there was no specification to the students that the questions had to be open-ended or complex. An evaluation of the Boat Motor project written project supplement reveals a four item concept inventory, as compared to >10 items other animation projects supplied. The expressed principles of operations were crude compared to other groups: “*The principles of operation that will be shown during the animation are the assembly and movement of the motor’s components.*”

The intended audiences specified for this project are: *Industrial Designers and Material Scientists* and yet the audience portion of the written supplement contained the following -

Audience-Heterogeneous

1. *[The] Audience expected to have general knowledge, engineering background not needed.*
2. *Audience expected to know what an outboard boat motor is and what it is used for.*
3. *Audience will come away from viewing this animation with the knowledge of how a two-stroke boat motor is assembled.*

While audience assumption 2 (above) is perhaps a fair one, the first is generic as it is not clear what is meant by “general knowledge”. As for the third statement, the question remains, does the audience walk away ‘knowing’ how a two-stroke boat motor is assembled? This question can’t be answered as the three author-provided questions do not address this stated message goals. Of note, this group did not attend the required working meeting during which time the scaffolding expectations for the project would have become clearer.

Garden Leaf Blower Project

*Garden Leaf Blower Questions*

1. *How is air moved through the device?*
2. *Where does the electric motor draw power from?*
3. *How do the magnets take the electric power and convert it to driving the shaft?*

Analysis:

While only five items are listed in this project’s concept inventory, the outlined principles of operation are focused and specific. *Air flow through device, electromagnetic functions of motor, transfer of power to fan, engaging power.* Further, the three author-provided questions directly address the primary message goals. These questions can be considered a success in that the questions are audience appropriate, well stated, and inline with the project message goals.

## Folding Bike Project

### *Folding Bike Questions*

1. *How does the bicycle fold to become more compact?*
2. *How do the wheels move?*
3. *How does the bicycle stop?*

### Analysis:

In general, this project had an excellent written supplement with questions that could be considered open-ended. The project authors supplied the following intended principles of operation:

### *What principles of operation will be illustrated?*

- *The pedals moving which causes the gears, chain, and wheels to move.*
- *The folding aspects of the bicycle: the hinges on the body, the lowering of the seat, and the hinge on the pedals.*
- *The brake levers moving which leads to the brake pads squeezing on the rim of the wheel.*
- *The handlebars turning which guides the front wheel.*

We can see from the questions and principles listed above that, question 3 maps to message goal 3 and that question 1 maps to message goal 2. Question 2 is a nice reverse questioning of message goal 1. Question 2 is a nice reverse restatement of message goal 1. Further, note that Question 1 is a subtle reversal of the order in which the subassemblies are presented during the technical animation, potentially calling for more complex thinking by the audience.

## Beer Launching Fridge Project

### *Beer Launching Fridge Questions*

1. *How gear, motor, spring and trigger contribute to the beer throwing motion in catapult?*
2. *How the motor/sprocket/rotating base turns the base of the catapult to the correct location to launch the beer?*
3. *How the switch/spring system on the car and elevator allows the beer to fall into the catapult bowl?*

### Analysis:

This project suffered some major challenges – including a final presentation missing 300 frames, the result being a jumbled presentation of the content. From the written project supplement there were 10 principle message goals, which should be considered ambitious.

These 10 goals were:

1. *How the magazine contains the beer and how the beer travels down the magazine*
2. *How the “L Beer Holder Trigger” holds the beer in the magazine*
3. *How the elevator triggers the “L Beer Holder Trigger” to allow the beer to fall into the elevator car*
4. *How the motor/sprocket/gear rack interact to bring the elevator car up*
5. *How the switch/spring system on the car and elevator allows the beer to fall into the catapult bowl*
6. *How the motor/sprocket/rotating base turns the base of the catapult to the correct location to launch the beer*
7. *How the trigger in the catapult locks the catapult arm*
8. *How the solenoid operates to unlock catapult arm*
9. *How the chain/gear/motor operates to turn the catapult arm*
10. *A motherboard and microchip triggers the entire system remotely*

Given the complexity of the author supplied questions, the ambitious number of message goals, and the incompleteness of the technical animation, this project would not be considered successful.

#### RC Helicopter Project

##### *RC Helicopter Questions*

1. *How do certain parts fit into the helicopter? (50)*
2. *How do three separate servos work together to create rotation about any axis? (50)*
3. *How does swash plate movement affect rotor tilt? How much freedom of motion are the blades capable of? (25)*

#### RC Helicopter – Written Supplement

*We attempted to illustrate all the concepts listed, especially focusing on servo-swash plate-blade interaction because this is what allows the helicopter to move freely in 3D space.*

1. *The Honey Bee CP2 is a beginner’s helicopter*
2. *Has separate tail and main motors*
3. *Uses battery power (vs. gas power)*
4. *Has stationary and rotating swash plate that is controlled by main gear and servos*
5. *Independent servos control swash plate tilt, orientation, and position*
6. *Servo coordination requires electronic controller to translate user input into movement*
7. *Several bearings allow freedom of motion of swash plate and blade tilt*
8. *Tilt of swash plate controls blade tilt*
9. *Blades vary degree of tilt as rotor disc rotates*
10. *Part installation is highly dependent on order*
11. *Two sets of blades of different sizes are suited for different functions, one for power, one for orientation*
12. *All parts made slender, as hollow as possible, and lightweight to decrease overall weight*
13. *Shell is aerodynamic to decrease drag*

Analysis:

Again, like the Beer Launching Fridge Project, this group had many intended message goals. Question 1 is the most ambiguous of the three – it being so open-ended may have presented a challenge to respondents.

#### Floppy Drive Project

*Floppy Drive Questions*

1. *How to read/write by magnetism? (0)*
2. *How to make direct contact with the disk? (50)*
3. *How to place the disk onto the correct position? (75)*

*Floppy Drive Written Supplement*

*Principles of operation to be illustrated*

*how to read/write by magnetism*

*how to make the direct contact with the disk*

*functions of mechanical components that place the disk onto the correct position*

*Target/Intended Audience*

*Target/Audience: Electrical Engineers*

*Our main audience is electrical engineers who have heterogeneous education and knowledge mainly through hands-on experience in the field of electrical devices.*

Analysis:

This project had the most uneven distribution of correct responses. The first question is a complex question and it is not clear what sort of answer would be considered complete and correct. In contrast to the first question, the second and third are more straightforward. Based on the clear and realistic message goals, the lower average comprehension of this project is attributed to the difficulty of the first question.

QUANTITATIVE ANALYSIS FELLOW PARTICIPANT REVIEW

During the *fellow participant review 2008*, the animation project viewers were asked to answer the three author-written comprehension questions as well as six scaffolding related questions. During the *fellow participant review 2008*, 34 students reviewed each of the 19 technical animation projects, totaling 646 reviews. These *fellow participants* having been exposed to the scaffolding methodology and its terminology, were asked six scaffolding related questions.

The six questions asked during the *fellow participant review 2008* were:

- 1 *Is the length appropriate? (Too long, too short, etc.)*
- 2 *Does the presentation approach and style help overall understanding?*
- 3 *Are there aspects of the animation that are overwhelming, distracting, or frustrating?*
- 4 *Weight & priority given to important aspects of device? Yes/no*
- 5 *Animation maintains big picture perspective while providing enough detail? Yes/No*
- 6 *Complementing media (good coordination of sound, motion, camera view, lighting). Yes/No*

The results of these reviews were tallied and summarized in the table below. Again, each project was reviewed 34 times and in this table a “1” would represent a fully positive response and a “0”, a fully negative one.

## SCAFFOLDING PERCEPTIONS

Table 5. Fellow Participant Review. Averaged Results by Project

	Final Project Grade	Is the length appropriate?	Does the presentation approach and style help overall understanding?	Are there aspects of the animation that are overwhelming, distracting, or frustrating?	Weight & priority given to important aspects of device?	Animation maintains big picture perspective while providing enough detail?	Complementary?	Scaffolding Average
DVD Burner	67	0.64	0.76	0.5	0.88	0.88	0.88	0.76
Floppy Drive	58	0.44	0.65	0.57	0.8	0.78	0.96	0.7
Leaf Blower	70	0.84	1	0.74	0.94	0.97	1	0.91
Folding Bicycle	69	0.86	1	0.5	0.93	0.96	0.89	0.86
Bat-mobile	71	0.71	0.68	0.59	0.89	0.85	0.97	0.78
Fishing Reel	67	0.81	0.79	0.77	0.93	0.93	0.86	0.85
Magic Bullet	71	0.47	0.82	0.7	0.89	0.97	0.96	0.8
Compound Bow	76	0.97	0.94	0.87	1	1	1	0.96
Electric Drill	68	0.77	0.77	0.52	0.91	0.97	0.93	0.81
Transfer Case	76	0.72	0.94	0.07	0.93	1	1	0.78
Camera Lens	72	0.58	0.97	0.73	1	1	1	0.88
Breadmaker	73	0.65	0.86	0.58	0.86	0.91	0.93	0.8
Canon Digital SLR	79	0.48	0.81	0.92	0.72	0.96	0.78	0.78
Beer Launching Fridge	62	0.42	0.59	0.35	0.86	0.68	0.59	0.58
Vacuum Cleaner	60	0.48	0.67	0.6	0.81	0.85	0.85	0.71
RC Helicopter	73	0.91	1	0.88	0.96	0.93	0.96	0.94
Playstation 2	77	0.96	1	0.71	0.81	0.96	0.89	0.89
MOMO Force Feedback Wheel	63	0.78	0.6	0.29	0.54	0.5	0.63	0.55
Boat Motor	67	0.59	0.96	0.65	0.9	0.9	0.95	0.83
Group Average	69.421	0.69	0.83	0.61	0.87	0.89	0.9	0.8

The perceptions of each project by fellow participants were generally high, with two exceptions: the Beer Launching Fridge Project and the MOMO Force Feedback Wheel Project. The Beer Launching Fridge Project suffered in the perception of length (0.42), meaning that viewers thought the length was inappropriate, and in the presence cognitive overload (0.35), meaning that viewers found aspects of the animation distracting or disruptive. The likely cause of this audience frustration was the project's 300 missing frames, which interrupted the narrative of the project, and left the project feeling short. The Force Feedback Wheel Project's low average score (0.55) can be attributed to low perception scores generally. The fellow participants did not respond favorably to this project and the project received low perceptual scores in all categories but length. Some comments provided by the review participants include: *Sound was grainy, lights were off, background was distracting, pace too slow, too short, ended without showing much operation*. Incidentally, these two projects received the second and third lowest grades based on the projects' technical requirements.

Averaging each of the perception categories reveals that the lowest scores are in the length and cognitive noise categories. Viewing these averages leads into an investigation of relationships between categories.

**CORRELATIONS** In the interest of understanding the interplay between the scaffolding principles, as perceived by the peer-reviewers, correlations were calculated using the averaged values of the six questions listed on page 59 for each of the animation projects.

Using the Pearson correlation equation, the evaluated scaffolding attributes were determined using the Pearson Correlation Coefficient.

Pearson's Correlation Coefficient.

The correlation between two variables or the degree to which there is a linear relationship between the two, with a range of -1 to 1. Equ:  $\text{covar}(x,y)/(\text{var } x^{1/2} - \text{var } y^{1/2})$

The Pearson Correlation Equation will identify the degree to which the two qualities/variables parallel each other. The significance and critical values of the correlation coefficients can only be determined in light of the body of results. Given the incredibly complex and varied context under which the study took place (multiple participants, little to no sleep by participants, etc.), critical values of correlation will be established after correlations between factors are completed.

**CORRELATION RATIO** ( $n$ )

The correlation ratio,  $n$  identifies whether most of the overall dispersion is a result of differences between topics, rather than within topics.

Correlations were calculated between scaffolding principles from the *fellow participant review 2008* results. At a 5% confidence level with a population of 19, correlations above 0.389 are considered significant correlations and values above 0.70 are considered strongly correlated.



Table 6. Scaffolding Principle Correlations

PRINCIPLE COMPARISON	SCAFFOLDING - BETWIXT	Pearson Correlation	Significant at 5% (with 19 projects 0.389)
1-2	Length & Presentation approach	0.56	Significant
1-3	Length & Cognitive Overload	0.16	Not Significant
1-4	Length & Priority	0.24	Not Significant
1-5	Length & Perspective	0.27	Not Significant
1-6	Length & Complementary Media	0.27	Not Significant
2-3	Presentation & Cognitive Overload	0.37	Significant
2-4	Presentation & Priority	0.59	Significant
2-5	Presentation & Perspective	0.76	Significant
2-6	Presentation & Complementary Media	0.64	Significant
3-4	Cognitive Overload & Priority	0.29	Not Significant
3-5	Cognitive Overload & Perspective	0.46	Significant
3-6	Cognitive Overload & Complementary Media	0.32	Not Significant
4-5	Priority and Perspective	0.75	Significant
4-6	Priority and Complementary	0.69	Significant
5-6	Perspective and Complementary	0.77	Significant

Nine of the 15 scaffolding principles were found to be significantly correlated. Strong correlations (>0.70) were found between :

- Presentation and Perspective (0.76)
- Priority and Perspective (0.75)
- Perspective and Complementary (0.77)
- Priority and Complementary (0.69)

Table 7. Significant Scaffolding Principle Correlations

1 length						
2 presentation	grey					
3 cognitive overload		grey				
4 priority		grey				
5 perspective		X	grey	X		
6 complementary media		grey		X	X	
	1 length	2 presentation	3 cognitive overload	4 priority	5 perspective	6 complementary media
grey'd boxes represent correlated principle and x's represent strong correlations						

A major conclusion here is that, while in Table 4, we saw that not all projects attempted to implement all 7 scaffolding principles, there are correlations between principles. This means that the successful application of only some of the scaffolding principles may achieve a well-scaffolding gestalt.

Of note is that the perception of the **Presentation Approach** was correlated to all other principles. While the Pearson correlation coefficient does not determine cause and effect, this does suggest that the consideration of **Presentation Approach** (Information Metaphor) is valuable. A potential interpretation of this result is that: how the information is presented, the determination of the animation's **Information Metaphor**, should be a primary consideration in the organization and composition of a technical animation, to some extent enveloping the consideration of **Information Priority**, **Use of Perspective** and **Complementing Media**.

It does make intuitive sense that the lack of **Cognitive Overload** (aspects of the animation which are distracting or frustrating) an ability of the finished animation project to maintain both a global **Perspective** while presenting enough detail would parallel each other. If audience members were unable to track the assembly and operation of the device, including its individual parts and subassemblies, through the animation's timeline and in and out of the viewing frame – this would be cause for cognitive overload. Inversely, if an audience was overwhelmed or distracted by factors such as flashy media, an inappropriate tempo or shaky camera motions, it could be difficult for viewers to track both the global and local perspective through the animation's trajectory.

Interestingly, the perception of **Length** was not correlated with any other principle but **Presentation Approach**, suggesting again that the perception of **Length** is tethered to the overall gestalt rather than another scaffolding characteristic of the animation.

AUTHOR  
SCAFFOLDING  
CONCLUSIONS

This chapter has looked at the ways in which the project authors ‘scaffolded’ the technical animation projects in order to address the second question of the Technical Animation Research Study: How do the authors implement the Information Scaffolding Framework?

The scaffolding process began with the creation of the concept inventory. The 19 groups provided concept inventories as short as four items and as long as the suggested 15 items. The Garden Blower project supplied one of the most generic concept inventories (*principles of operation, use of device, engaging cinematics, contextualization of device, impact of device*) and the RC Helicopter provided one of the more specific concept inventories (*i.e., the honey bee cp2 is a beginner’s helicopter, shell is aerodynamic to decrease drag, etc.*). Both of these projects applied the scaffolding principles well and despite the Garden Blower’s items seeming overly simple and the RC Helicopter’s incredibly specific, they are examples of the necessary type of specificity by the authors.

Were the technical animation projects informed by the choice of audience and subsequent audience assessment when addressing the project message goals? Not enough.

The evaluation showed that the methodology lacked a set of even more specific audience assessment tools. The analysis also showed that again and again the scaffolding process was less effective because the synthesis of the audience assessment and the document message goals did not occur. Even for the spring 2008 intervention, despite improvements on the earlier iterations, the audience assessment could have been clearer.

Consider the five projects that selected *Other* as an intended audience. Of these five projects, two projects identified general audiences and three identified specific audiences. The three specific audience types were simply ‘enthusiasts’ of the depicted device, for the Batmobile – Batman enthusiasts, for the Fishing Reel – fishing enthusiasts, and for the Compound Bow – archery enthusiasts. This is, to some degree, inappropriate to the exercise as it assumes an ingrained interest in the subject matter and some level of expertise. On the other hand, four of these five projects with *Other* audience types fared very well in the final grading and the established scaffolding measures.

An obvious conclusion is that when it comes to a ‘general audience’ you can address this unknown audience well or poorly, the key being whether or not this an explicit choice. A recommendation would be to have a feedback cycle with the intended audience, during which time the authors would have an opportunity to question assumptions made about the intended audience or perhaps to get comprehension feedback on a draft of the finished product.

As an example of an opportunity primed for a feedback cycle, consider this written statement from the Transfer Case Project:

*We suspect the audience already knows that four wheel drives are better in low traction situations. We don't think they've heard of a transfer case. They just want to know its purpose and how complex it is (likelihood of failure, for if they ever decide to buy a 4wd vehicle) .*

The 7 scaffolding design principles have always been meant to serve as heuristics - general concepts through which authors might frame their use of media. An important result is that the animation projects which scored highly in the perceptions by fellow students, generally scored highly in each aspect of the scaffolding perceptions. This was independent of number of principles the authors indicated using, where in some instances the project authors indicated addressing all of the principles and in other cases the authors indicated using only one or two. This suggests the presence of a conscious or unconscious understanding between group members regarding the selection and use of construction principles.

A key difference between projects is in the number of message goals. Project groups that had more success were groups that selected a handful of clear principles of operation to focus on. This is in concert with a hypothesis of Information Scaffolding, which is that prioritizing a few key points is

better than not (anecdotally three or four seems prudent). This mapping however does not need to be verbatim and blunt, as witnessed in the Folding Bike project where the third question was a subtle reversal of the order in which the animation subassemblies were presented.

In evaluating the scaffolding of the authors, they suffer, as all authors do, multimedia or otherwise, in that what audience members experience is only the resulting product and not the process of construction. A subtle, but vital aspect of Information Scaffolding is to encourage authors to provide audiences with insight into a portion of the author's thought and information organizing processes. This is both for the benefit of the learning process and to help the audience understand where authors are 'coming from' in order to recognize a point of view and the scope of the information provided. This also is another way of strengthening the connections between members in a given knowledge society [Scardamalia '02, '06, '07. Gan '07].

This chapter revealed reconsiderations for both authors interested in constructing user-centered documents and for the iterative improvement of the Information Scaffolding method. These fundamental lessons include:

1. When it comes to information contained within the project, authors need to verify that this information is aligned with their message goals - is necessary information conveyed?
2. When writing questions, scaffold for the audience what might define an acceptable answer and with what level of detail.
3. The use of vocabulary needs to be consistent between the animation title, within the animation and comprehension questions.
4. For the Information Scaffolding method, the correlations between scaffolding principles suggest a tiered consideration when applying them. The Information Metaphor should be a primary consideration in the organization and composition of a technical animation, with the **Information Priority, Use of Perspective** and **Complementing Media** to be informed by this choice, and then again at the conclusion to the project (or first draft). Length and cognitive load being considered last. Before concluding the project, authors may ask themselves:

1. Does the **Information Metaphor** hold?
2. Then do **Information Priority, Use of Perspective** and **Complementing Media** complement this metaphor or detract from it?
3. Finally, do the **Length** and presence of **Cognitive Noise** unnecessarily burden the audience or distract from the message goals?

In Chapter 8, a content analysis is conducted wherein the animation projects are reviewed to determine their audience-centeredness. Based on the observations above, three aspects of the content analysis include: the presence of the author-intended concepts, consistency of vocabulary and finally the appropriate framing of the animation project.

## 7 Quantitative and Qualitative Assessment of Audience Perception & Comprehension

**INTRODUCTION** The intent of Information Scaffolding is to aid “everyday” authors in designing audience-centered documents. The 3<sup>rd</sup> iteration of the Information Scaffolding intervention in the Spring of 2008, yielded a set of technical animation projects with enough information about the intended audience to test the perceptions of actual intended audience members.

Two additional audiences were surveyed for their perceptions of the finished technical animation projects and for their comprehension of the projects’ intended message goals (adding to the perceptions discussed in Chapter 6 from the *fellow participant review 2008*). The structure of this chapter begins with a presentation of the perceptions of *intended audience survey 2009* participants for qualitative assessment. Second, a synopsis of the *2010 animation critique* is presented for quantitative comparison of scaffolded technical animation projects and projects without formal training.

**INTENDED AUDIENCE SURVEY 2009** For the spring 2008 intervention, animation authors were asked to select from four potential audiences, all of which were different from mechanical engineering but still likely to be exposed to technical animation. Authors were to assume all of these audiences were intelligent college educated non-mechanical-engineering experts. The intended audience choices were:

- Electrical Engineers [EE]
- Material Scientists [MS]
- Business Decision Makers [BDM]
- Industrial Designers [ID]

All 19 projects did identify an intended audience and attempted, to varying degrees, to let this intended audience inform the design on the technical animation project. *OTHER* was not given as an intended audience option. However, five projects chose to address audiences other than the four listed above. Of these five projects, two projects identified general audiences and three identified specific audiences different than the four above. The three specific audience-types were ‘enthusiasts’ of the depicted device, for example the Batmobile had an intended audience of Batman enthusiasts.

For the 2009 *Intended Audience Survey*, six intended-audience members – experts in one of the four 2008 suggested intended-audiences, graciously participated in the 30-60 minute online survey. The professions of the participants breakdown thus:

- 4 in Design / Art
- 2 in Science and Engineering

The six participants each watched a subset of six animations for a total of 20 viewings, as show in table 8. The primary insight is that only six of the 20 viewings were by members of the audience the authors intended. Portions of the following chapter investigate whether it is the targeting of a specific audience or the process of audience investigation and demography that led to successful finished products for intended and unintended audiences.

Table 8. Intended Audience Survey Participation Results

Participant	Canon Digital Camera	Compound Bow	Electric Drill	Fishing Reel	Garden Leaf Blower	Remote Control Helicopter	Transfer Case
Intended Audience	EE	Other (general)	Other (general engineers and designers)	Other (fishing enthusiast)	Other (mechanical engineering community)	ID	BDM ID
Designer 1							
Designer 2							
Designer 3							
Designer 4							
Material Scientist 1							
Material Scientist 2							
Total Views	5	2	4	5	2	1	1
Intended Audience Participants	1	0	4	0	1	1	0
Unintended Audience Participants	4	2	0	5	0	0	1

INTENDED  
AUDIENCE  
SURVEY 2009  
GENERAL  
PERCEPTIONS

The general comments supplied by the six intended-audience participants were insightful. A major portion of Information Scaffolding is motivating authors to re-frame the authoring process, viewing the exercise not as a simple documenting process (author-centered) but instead as a process of informing (audience-centered).

The frustration of the survey participants was evident, as seen with comments like:

*I understand that it is a class project, so it is very well done, great work, etc.--if I were a student or teacher for the class or a camera buff. But since I wasn't interested in this level of detail, I got the general idea early on, and was dying for it to end. Stopped paying attention after about 3 minutes, it got repetitive seeing parts and screws "flying" slowly into place. So I didn't really learn anything, had to wait forever for the ray diagrams/lens focus. I REALLY hope the next two videos aren't this long! -- Material Scientist*

and,

*I think I'm a little unclear who this video is for. It seemed most applicable for someone who needed to assemble or disassemble the camera. -- Designer.*

It is also clear from the written comments (included below) that the audience members were not interested in the assembly aspects of the animation, feeling that the authors put an inappropriate amount of weight and priority on assembly.

*Stopped paying attention after about 3 minutes, it got repetitive seeing parts and screws "flying" slowly into place. So I didn't really learn anything..had to wait forever for the ray diagrams/lens focus.*

*--- of the Digital Camera Project*

*Great visual focus on how it works a rather than too much focus on the assembly of its parts. and,*

*I am not mechanically inclined, nor am I a visual learner, so this really didn't engage me or teach me anything. I think it would be much more powerful with some words (voice over or caption.)*

*--- of the Garden Leaf Blower Project*

The desire of this audience to minimize the assembly portions of the completed animation projects is in direct conflict with the project assignment, which was to show the assembly and operation of a moderately complex mechanical device. Nevertheless, this is a realistic challenge of the authoring process – balancing the needs and motivations of both the audience and the authors, and the viewers did indicate that the Fishing Reel Project, for example, successfully incorporated the assembly of the device with minimal audience frustration. Based on this observation, perhaps future revisions of these projects should prioritize the contextualization and efficiency of the assembly portions for the sake of their audience, ameliorating this source of frustration.

INTENDED AUDIENCE PERCEPTIONS For the 2009 Intended Audience Survey, the participants were indirectly asked for their scaffolding perceptions through the use of three questions. The wording of the perception related questions are listed below:

1. *Is the length appropriate? (Too short, A bit short, Just Right, A bit long, Too long)*
2. *Does the presentation approach and style help overall understanding? (yes/no)*
3. *Are there aspects of the animation that are overwhelming, distracting, or frustrating? (yes/no)*

The participant responses to these three questions are now presented with hope of informing both the iterative revision of the information scaffolding methodology and to begin to assemble a list of recommendations for the construction of audience-centered technical animations.

PROJECT LENGTH IS THE LENGTH APPROPRIATE? This question is attempting to understand what role the length of the finished animation project plays with respect to the viewing audience. The following comments were provided by the survey participants.

*Much too long, unless digital camera assemblies happen to be your personal obsession!*  
*--Digital Camera (9 minutes 55 seconds)*

*I felt like watching the entire camera being constructed was really long, whereas some of the animations in the last 2 minutes showing function were more enlightening.*

--Digital Camera (9 minutes 55 seconds)

*The animation went fast for confusing parts and slow for the parts that were obvious and,*

*I picked this video b/c it was 3 minutes long (unlike the camera at 10 minutes!)*

-- Garden Leaf Blower (3 minutes 40 seconds)

*Stopped paying attention after about 3 minutes, it got repetitive seeing parts and screws "flying" slowly into place.*

-- Camera Lens Project (9 minutes 55 seconds)

Overall the length ratings tell this story; of the 20 responses 10 participants, or half, rated the length as *just right*. The Electric Drill Project at 5 minutes 36 seconds, received all *just right responses*. **No participant rated any project too short or a bit short.** Eight respondents rated the various projects *a bit too long*, and two of five participants found the *Camera Lens Project*, the longest project at 9 minutes and 55 seconds *too long*.

Comments such as, *the animation went fast for confusing parts and slow for the parts that were obvious and regarding ... how a camera works, that information was really contained only in the last 2 minutes*, led to a suspicion that there are other aspects of time (tempo, priority) as well as in some manner the audience's expectations of the project's narrative (information metaphor or logic model) or even more simply the audience's grasp of the project's thesis, involved here. While what those factors are can not be determined from the available data, it is clear that for some, projects as short as 3 minutes and 40 seconds were perceived as too long.

PRESENTATION APPROACH. DOES THE PRESENTATION APPROACH AND STYLE HELP OVERALL UNDERSTANDING?	Having established the survey participants' instinctual perceptions of at least one aspect of the viewed animations - length, the next question looked to discover how the presentation approach struck the viewers. For this question participants were asked to provide a simple yes or no, with an additional comment section not being provided.
	With 20 responses, 18 affirmed that the <i>presentation approach and style helped overall understanding</i> . Only one person did not feel the <i>Camera Lens Project</i> was presented in a way that helped overall understanding, and 1 person felt this way about the <i>Garden Leaf Blower Project</i> .

*Camera Lens --*

*This is much too long for an average viewer. I understand that it is a class project, so it is very well done, great work, etc.--if I were a student or teacher for the class or a camera buff. But since I wasn't interested in this level of detail, I got the general idea early on, and was dying for it to end. Stopped paying attention after about 3 minutes, it got repetitive seeing parts and screws "flying" slowly into place. So I didn't really learn anything.had to wait forever for the ray diagrams/lens focus. I REALLY hope the next two videos aren't this long! Nice music, though.*

*I think I'm a little unclear who this video is for. It seemed most applicable for someone who needed to assemble or disassemble the camera.*



*Leaf Blower --*

*Overall it was really good, but some audio guide with text, would have been very helpful.*

*I am not mechanically inclined, nor am I a visual learner, so this really didn't engage me or teach me anything. At least the N/S poles on the magnet were a start! Lovely, very soothing music though.*

Nevertheless, the presentation style and approach of all of the projects was very high. This result bodes well for desired flexibility of the Information Scaffolding approach, which looks to not inhibit the authors' creativity or individual presentation style while redirecting the finished product's POV towards audiences.

COGNITIVE OVERLOAD: ARE THERE ASPECTS OF THE ANIMATION THAT ARE OVERWHELMING, DISTRACTING, OR FRUSTRATING? Twelve of the 20 respondents indicated some type of frustration or annoyance, although, in any animation it is easy to find some aspect of irritation. All of the cognitive overload section comments are listed below, most of which are specific rather than major indictments of the project's construction.

Comments:

- *Appears blurry in full screen mode.*
- *I felt like watching the entire camera being constructed was really long, whereas some of the animations in the last 2 minutes showing function were more enlightening.*
- *The beginning 4 min of all the intricate parts being placed together - The initial explosion of parts just gets confusing -*
- *Background.*
- *The reorientation of parts once they are brought into the field of view seems unnecessary. the music is good, but distracting. it is blurry in full screen mode.*
- *I would have preferred a constant close up zoom for some of the mechanism scenes.*
- *The changing zoom was a bit irritating at times. Maybe I'm just in a bad mood.*
- *not a fan of the light pink background looks blurry in full screen mode.*
- *At times I felt like some components were made transparent when their presence would have helped me better understand what was going on.*
- *At the beginning, the point of reference was lost on the zooming in of groups of parts from the exploded view.*

COMPREHENSION The three comprehension questions were also included in the intended audience survey in 2009, however, no substantive changes were achieved in comprehension. From reviewing the perceptions and comprehension of the intended audience, it is apparent that the intended audience members were primarily frustrated with the set up and framing of the animation projects.

Generally, participants had strong instincts about how the devices worked in spite of being unfamiliar with the devices in particular. For example, one participant commented that she/he didn't personally fish, but nevertheless answered the comprehension questions correctly.

The lack of specification by the authors in illustrating the intended message goals was evident during the 2009 Intended Audience Survey. Three times participants commented in the questions following the animation that they felt the information asked in the question was not contained in the technical animation.

With only six of the 20 *intended audience survey* participants being members of the author-specified intended audience and yet the comprehension of the participants being equivalent for intended audience members and unintended members, a future research question emerges: is the information scaffolding process of addressing a specific audience type necessary or is the process of the audience demography, if reformed, enough to bring shape to the preparatory set of audience evaluation?

INTRODUCTION To conclude the Information Scaffolding Technical Animation Research Study, 56 students were surveyed for their perceptions, serving as audience members of the completed technical animations. The students viewed five animations, two of which were well scaffolded, one of which was poorly scaffolded and two which were well constructed but whose authors did not receive the information scaffolding intervention.

QUANTITATIVE  
ASSESSMENT

The 56 students performing the evaluation were enrolled in the upper division Mechanical Engineering 110 Product Design course, taught in the spring 2009 semester. The class included students majoring in: mechanical engineering (44), industrial engineering and operations research (1), electrical engineering and computer science (1), english (1), rhetoric (1), business administration (2), material science (2), environmental economics and policy (1), civil engineering (2), cognitive aesthetics (1).

Of the five technical animation projects, two implemented the Information Scaffolding methodology well, two were created without any exposure to the IS methodology and the fifth animation was constructed using the IS methodology but was rated poorly in its execution by expert reviewers.

The five projects reviewed were:

1. Pocket Watch (no scaffolding)
2. Electric Shaver (no scaffolding)
3. Electric Drill (scaffolding)
4. Compound Bow (scaffolding)
5. Chainsaw (scaffolding)

SUMMARY  
OF RESULTS  
NUMERICAL  
AVERAGES

The ME 110 students watched each of the animations and were then asked to answer the following questions:

1. *Does this animation seem to provide a complete description of the device? In the same way an essay or presentation can seem complete or incomplete. From 1-5, 1-definitely missing information, 3-some additional information needed, 5-complete.*
2. *How many times would you need to watch this video in order to explain the assembly of this device?  
1-10*
3. *How many times would you need to watch this video in order to explain the operation of this device?  
1-10*
4. *Does the presentation style make the assembly and operation of the device memorable to you? Yes/No*
5. *List 5 functions or components of the device:*

SURVEY	Does the presentation style make the assembly and operation of the device memorable to you?
ANALYSIS:	
DEVICE	Memorable Projects Ranking:
DESCRIPTION	Electric Drill 98%
<i>Does the presentation style make the assembly and operation of the device memorable to you?</i>	Compound Bow 94%
	Pocket Watch 75%
	Shaver 62%
	Chainsaw 27%

The projects which presented the devices in ways which were most memorable to the surveyed audience were the two projects that were well scaffolded. There was a significant distinction between these projects and the two that were not scaffolded. The Chainsaw project, which had exposure to the scaffolding methodology but where none of the principles were evident in the finished project, was utterly non-memorable to the surveyed audience.

SURVEY	This trend continues as the results from the other questions are analyzed, further indicating consensus within the audience. When asked <i>Does this animation seem to provide a complete description of the device?</i> The general ranking of the projects is similar, with the two non-scaffolded projects being switched in order:
ANALYSIS:	
PRESENTATION	
STYLE	
<i>Does this animation seem to provide a complete description of the device?</i>	Electric Drill (4.875/5)
	Compound Bow (4.36/5)
	Shaver (3.848/5)
	Pocket Watch (3.1/5)
	Chainsaw (2.73/5)

SURVEY	Interesting results also present themselves when the audience was asked how many times they would need to rewatch the animation in order to be able to explain the assembly or operation of the device.
ANALYSIS:	
<i>Rewatch Results</i>	

Table 9. Audience Rewatch Results

How many times would you need to watch this video in order to explain the <b>assembly</b> of this device?		How many times would you need to watch this video in order to explain the <b>operation</b> of this device?
Electric drill 2.696 - scaffolded		Electric drill 1.625 - scaffolded
Shaver 3.3 - unscaffolded		Shaver 1.81 - unscaffolded
Compound bow 3.52 - scaffolded		Compound bow 2.12 - scaffolded
Pocket Watch 5.26 - unscaffolded		Pocket Watch 3.34 - unscaffolded
Chainsaw 5.43 - poorly scaffolded		Chainsaw 4.38 - poorly scaffolded
* unscaffolded means projects without formal scaffolding training		

It is interesting that the rankings in Table 9 exactly parallel each other. However, the averages are distinctly different from question to question and so it is likely that participants weighted the two sections of presentation (assembly and operation) differently. The participants clearly felt that they would need to view the assembly of a device more times in order to explain it than the operations. This is an important result with implications for animation authors who are trying to explain procedural types of information. One hypothesis is that because there are a number of ways to assembling a device, or because the audience does not have a rationale for the assembly, it is difficult for them to ‘learn’ it.

What is also interesting is the mingled rank of the scaffolded and unscaffolded projects. Both scaffolded projects required relatively few views (participants in general may have minimized the number of views either because of pride or more likely because they unconsciously determined to what degree they would need to ‘explain’ the device). It may also be that the unscaffolded projects inadvertently addressed some of the key scaffolding principles without training. The unscaffolded projects were selected from the other animation projects for being the more cogent and technically successful projects. In Chapter 8. Content Analysis, these two unscaffolded projects are evaluated using the same metrics for determining audience-centeredness.

What is different about the Shaver project and the Pocket Watch? Given that they were both unscaffolded - what made the Shaver more effective? Both were well done projects but like the scaffolded projects the Shaver presented a sort of logic. As will be seen in the Content Analysis presented Chapter 8, the Shaver had a *narrative*, provided enough time for *registration* and had strong *relationships* between parts and groups of parts.

This set of results indicate that the two scaffolded projects seemed the most complete to the audience members. Audience members had more difficulty grasping the assembly portions than the operation portions. These results also indicate that when the authors have a clear understanding of a device (operation and assembly) and present the device with an underlying logic that understanding is more ‘legible’ to an audience as is seen in the contrast between the Electric Drill, Shaver and Compound Bow versus the Pocket Watch and the Chainsaw.

The students were also asked to list five functions or components of each device described in the technical animation. Overwhelmingly, the participants listed components, with functions being an infrequent exception. Looking at the vocabulary, each project had a handful of descriptors which were used more frequently. Only the most high level describing terms were used - *fuel tank*, *piston and handle*, for example. This becomes important to authors in two ways. 1. Should authors need or want their audience to know or learn unique vocabulary – they must find a way of introducing it. 2. This data helps to indicate what features the audience attended to while watching the animation. This may in part be a function of a catch 22, meaning that parts listed were the parts which the audience members had the vocabulary to describe. Nevertheless, this practice is an important one for identifying which features stick with an audience.

The next chapter, Content Analysis, is informed by the results of this and the preceding chapter in order to define metrics for evaluating the audience-centeredness of technical animations. This chapter identified three new aspects for the content analysis, which are closely tied to key scaffolding design principles. These three new facets of the content analysis are: Storyline, Part Relationships, and Registration.

## 8 Content Analysis

**INTRODUCTION** Previous chapters looked at the manifestations of the author's scaffolded design efforts and at the 2008 projects from the intended audience and fellow student perspectives. This chapter provides an additional formative assessment from an expert perspective with the goal of identifying attributes for formative project improvement and generalized technical animation authoring recommendations. This content analysis started by viewing all of the 2008 projects as the authors had gone through the scaffolding process. The evaluation took the formative perspective by asking the question: "With an additional iteration, how could this animation be improved for audience members?" All of the 2008 projects had been previously graded based on using technical specifications, so the answers to this question could be directed towards improvements in scaffolding for the audience's benefit.

The desired outcomes of this learning-centered, content analysis were:

1. Characterization and ranking of 2008 projects with respect to audience centeredness - *which projects met both the technical and scaffolding specifications best?*
2. Recommended modifications to the Information Scaffolding Methodology for Technical Animation.
3. Generalized Recommendations for the construction of Technical Animation.

*Chapter 6: Audience Perceptions & Comprehension* and *Chapter 7: Author Scaffolding* presented six challenges affecting the audience's ability to take away the intended message goals for later use in differing contexts.

**FACETS OF ANALYSIS** The content analysis was conducted by two of the E128: Advanced Engineering Graphical Communications assistant instructors, both of whom participated in the course as students during previous years and assisted in the classroom for a total of six semesters. Eighteen of 19 projects were evaluated using the six measures of audience-centeredness derived from the results of the previous chapters.

**INTENDED CONCEPTS (2 PTS)**

1. One major issue arose from the *intended audience survey 2009*: in some cases the projected related comprehension questions were not actually present in the technical animation. In this content analysis study, all projects were reviewed asking: *Are the intended concepts present - and to what degree? Could an audience member find the answers to the author provided comprehension questions within the animation project?* The 19 projects were ranked according to the presence of the intended concepts and the depth to which the authors explained these concepts. The projects were then given 1/10th of the ranked score (with 19 projects and Intended Concepts category being worth 2 points; projects received 0.2 - 1.9 points).

**FRAMING (2 PTS)**

2. The major issue expressed by participants in the *intended audience survey 2009* was a general lack of evident purpose in the projects. While the assignment might have been clear to the authors and the course instructors, (e.g., illustrate the assembly and operation of a moderately complex mechanical device), it appeared not to have been obvious to the audience. Furthermore, it wasn't clear to the audience what they were supposed to get out of each project.

Research stresses the value and importance of framing information for the retention of quality learning, allowing the viewer to relate new information to prior knowledge and motivation. Noting

that decontextualized knowledge does not give us the skills to apply our understandings to authentic tasks, [Duffy '92] when not working with the concept in an authentic environment and experiencing the complex interrelationships in that environment, it is difficult to determine how and when the concept is to be used. This is especially important when striving to achieve long term knowledge transfer; knowing that untethered knowledge is easily lost in/from memory and is significantly more difficult to retrieve from long-term memory in contrast to knowledge which is strongly interconnected to many facets of an individual's mental model.

Each project was given either 2 or 0 points. The reviewers asked if the device was properly framed and contextualized for an outside viewer by asking: If the viewer did not know the assignment would they understand the purpose and narrative of the animation? In other words, does the animation of the device stand on its own?

3. **STORYLINE**  
(2 PTS) One of the elemental analysis modes of film critique is to ask if there is a strong, well-structured storyline – not necessarily linear or narrative, but a cogent underlying thesis or thread that binds the film's elements together. Decontextualized information often does not provide the motivation. Likewise, the animation projects need to sustain viewer interest. The reason motion pictures, for example, are accessible to a range of viewers is, in part, because they supply their own, self-contained motivation, the need for the animation projects to present well-defined relationships to the animation as a whole becomes important. Giving this category 2-points, projects were awarded full marks if the reviewers were able to easily articulate the sequence of events after viewing the animation. When this was difficult, the project was given 0 points. [Cubitt '05]
4. **PART RELATIONSHIPS**  
(1 PT) One of the unique challenges of this technical animation assignment is how to present dozens of mechanical parts with purpose. Many projects, from the 2008 set of animations and in years past, have developed compelling methods for the presentation of parts in a manner that contextualized the addition of other parts in the scene. Reviewers asked: Is the presentation of parts appropriate. Is there meaning behind the initial introduction of a collection of related parts? Is there clear meaning behind the introduction of parts and of families of related parts? When a project successfully introduced parts and subsequently related parts the project was given 1 point, when this was unsuccessful 0 points were given. [Rose '05]
5. **REGISTRATION**  
(1 PT) The question of appropriate project length was emphasized during the 2008 Information Scaffolding intervention and was evaluated to the extent possible in the previous two chapters. Here the evaluators look at tempo of the projects on the local scale. Knowing that it takes a full second to read and register the contents of a street sign [Hamilton '37, Furniss '98], is time appropriately allocated to the registration of key conceptual aspects of the device? Is the audience given adequate time to register and process when key points are being made?
6. **VOCABULARY**  
(1 PT) Is the use of vocabulary consistent between the title, the device and the comprehension questions: Is the vocabulary audience-appropriate? Can the intended audience connect with the animation and device given the vocabulary used? In the Transfer Case project the title Transfer Case is self-explanatory for audience members who know what a Transfer Case is. But for those who do not; thus a major portion of the animation is lost. Vocabulary use is evaluated both because the audience does not have to translate what they see into words to process the information in the animation and, as mentioned earlier, authors and viewers may use different words to describe the portrayed phenomena. [Savin-Baden '04].

EQUATION In order to rank the projects, the six measures above were given a value of 2 or 1 points, and then summed to provide a final concept inventory score.

Table 10: Content Analysis . Ranking Equation

Intended Concepts	+	Framing	+	Storyline	+	Part Relationships	+	Registration	+	Vocabulary	=	Total
.1 x rank		2		2		1		1		1		< 9

Recall from the theory and method of Information Scaffolding that the central aims are to construct documents which,

- Keep the big picture central and in focus
- Organize and support the comprehension process
- Place a premium on clarity, clear direction and minimizing confusion

\*[adapted from McKenzie '99]

and that Information Scaffolding hopes to supplement the *set of simple design principles/suggestions from education, design and information science for the scaffolding and composition of information* with researched technical animation construction principles. Clear successes in regard to the three tenets of Information Scaffolding are the top ranked projects: the Compound Bow, the Electric Drill, the RC Helicopter, the Canon Digital SLR, the Transfer Case and the Boat Motor.



Table 11 Ranked Content Analysis Project Scores

Project Title	intended concepts ranking 0 - 2	assignment framing 0, 2	narrative sequencing 0, 2	part contextualization 0, 1	vocabulary 0, 1	registration 0, 1	Total	Comments
Compound Bow	1.8	y	y	y	y	y	8.8	concepts slightly abstract
Electric Drill	1.6	y	y	y	y	y	8.6	no cause and effect in operation
RC Helicopter	1.9	y	y	y	n	y	7.9	
Canon Digital SLR	0.9	y	y	y	y	y	7.9	
Transfer Case	1.7	y	y	y	n	y	7.7	assumes viewers know the purpose of a transfer case
Boat Motor	1.5	y	y	y	y	n	7.5	
Folding Bicycle	1.3	y	y	y	y	n	7.3	lacking substance. illogical presentation
Breadmaker	1.2	y	y	n	y	y	7.2	parts are untethered
Playstation 2	0.7	y	y	y	y	n	6.7	intended concepts abstract
Leaf Blower	1.1	y	n	y	y	y	6.1	
Vacuum Cleaner	0.2	n	y	n	y	n	5.9	
Batmobile	0.5	n	y	n	y	y	4.5	no operation shown
DVD Burner	1.0	n	y	n	n	n	3.0	
Fishing Reel	0.8	n	y	n	n	n	2.8	
Floppy Drive	0.3	n	y	n	n	n	2.3	
Camera Lens	1.4	n	n	n	n	n	1.4	illogical presentation
Magic Bullet	0.6	n	n	n	n	n	0.6	lacking cause and effect
MOMO Force Feedback Wheel	0.4	n	n	n	n	n	0.4	
Beer Launching Fridge								project unavailable

UNSCAFFOLDED  
 TECHNICAL ANIMATIONS  
 INCLUDED:  
 SHAVER & POCKET WATCH

Table 12 . Ranked Content Analysis Project Scores with Unscaffolded Projects Added

Project Title	0 , 2 (intended concepts ranking)	0 , 2 (narrative sequencing)	0 , 1 (part contextualization)	0 , 1 (vocabulary)	0 , 1 (registration)	Total (7)	Comments
Compound Bow	y	y	y	y	y	7	concepts slightly abstract
Electric Drill	y	y	y	y	y	7	no cause and effect in operation
<b>Shaver</b>	<b>y</b>	<b>y</b>	<b>y</b>	<b>n</b>	<b>y</b>	<b>6</b>	
RC Helicopter	y	y	y	n	y	6	
Canon Digital SLR	y	y	y	y	y	7	
Transfer Case	y	y	y	n	y	6	assumes viewers know the purpose of a transfer case
Boat Motor	y	y	y	y	n	6	
Folding Bicycle	y	y	y	y	n	6	lack ing substance. illogical presentation
Breadmaker	y	y	n	y	y	6	parts are untethered
Playstation 2	y	y	y	y	n	6	intended concepts abstract
Leaf Blower	y	n	y	y	y	6	
<b>Pocket Watch</b>	<b>y</b>	<b>1</b>	<b>y</b>	<b>n</b>	<b>y</b>	<b>5</b>	
Vacuum Cleaner	n	y	n	y	n	3	
Batmobile	n	y	n	y	y	4	no operation shown
DVD Burner	n	y	n	n	n	2	
Fishing Reel	n	y	n	n	n	2	
Floppy Drive	n	y	n	n	n	2	
Camera Lens	n	n	n	n	n	0	illogical presentation
Magic Bullet	n	n	n	n	n	0	lacking cause and effect
MOMO Force Feedback Wheel	n	n	n	n	n	0	
Beer Launching Fridge							project unavailable

Chapter 7 had an unanswered question regarding the comparison of scaffolded and unscaffolded projects. While a full content analysis of the Shaver and Pocket Watch projects is not possible, because the intended concepts are unknown, the projects can be evaluated using the remaining five content analysis metrics.

The content analysis of the unscaffolded projects revealed a similar ranking to how the audience members rated the projects during the 2010 critique (as discussed in Chapter 7). This indicates that these unscaffolded projects did intuitively address some of the scaffolding principles.

COMPARING  
EXEMPLARY  
PROJECTS

Table 13. Comparison of Top Ranked Projects

Project Title	content analysis total	content analysis comments	final technical grade (max 80)	<b>perception scaffolding average</b>	comprehension score	number of message goals
Compound Bow	8.8	concepts slightly abstract	76	0.96	0.83	10
Electric Drill	8.6	no cause and effect in operation	68	0.81	0.92	3
RC Helicopter	7.9		73	0.94	0.42	13
Canon Digital SLR	7.9		79	0.78	0.50	3
Transfer Case	7.7	assumes viewers know the purpose of a transfer case	76	0.76	0.83	3
Boat Motor	7.5	abstract	67	0.83	1	broad

The six projects listed in Table 13 (above) all scored highly during the content analysis, the final project grade and the scaffolding perceptions. Where these six projects differ is in the comprehension scores and the number of attempted message goals.

The two projects which did not fair well in comprehension were the RC Helicopter and the Canon Digital SLR. The RC Helicopter had a single difficult question whereas the Canon Digital SLR had a low average comprehension score of 50 [*how does the image actually get to your eye?* (25), *how does the lens focus?* (75), *what are the sounds that the camera makes and where do they come from?* (50)]. The first of the Canon Digital SLR questions was oblique, the second was more concrete, and the third was specific to the particular model.

As for message goals, it is clear that authors are better off focusing on a few well-chosen message goals over many tangentially related ones. An investigation of these top ranking projects indicates that projects with a limited number of message goals that mapped well to the comprehension questions and which were well illustrated using animation, had the highest comprehension scores by *fellow participants*. The two projects which fared best in this respect were the electric drill and the transfer case.

# Conclusions & Future Research

9 conclusions

10 future research & next steps

# 9 Conclusions

INTRODUCTION Recall that the aim of the Information Scaffolding: Technical Animation Research Study was to identify how the information scaffolding methodology supported the construction of audience-centered technical animations, helping authors to improve understanding by:

- Keeping the big picture central and in focus
- Organizing and supporting the comprehension process
- Placing a premium on clarity, clear direction and minimized confusion

This study investigated how and under what circumstances the Information Scaffolding approach aided the construction of technical animations. The study reviewed and evaluated a set of 19 technical animations and their process of construction from three perspectives.

1. By reviewing how authors implemented the Information Scaffolding Framework. (Chapter 6)
2. From the perspective of a range of audience members by looking at audience perceptions and the degree of comprehension. (Chapters 7)
3. By conducting a expert-based content analysis to characterize the content of the finished product. (Chapter 8)

Also recall that before the introduction of the Information Scaffolding Methodology, the finished projects successfully met all of the technical grading requirements, but each year many of the groups failed to produce a cogent and compelling animations which successfully provided consistent information takeaways and transferable learning. With the introduction of the Information Scaffolding methodology the collection of finished products significantly improved in audience-centeredness and the accessibility of the animated devices. The conclusions in this chapter are presented in three sections:

- Significant study conclusions
- Recommendations for technical animation construction
- Review of technical animation study methodology

## Significant Study Conclusions

- 1. Broadly, what characterized the most successful technical animation projects?**
- 2. What conclusions can be drawn about comprehension?**
- 3. Were the technical animation projects informed by the choice of audience and subsequent audience assessment in addressing the project message goals?**
- 4. Scaffolding Design Principles. What conclusions were drawn from the initial 6 scaffolding principles? and more?**

### **1. Broadly, what characterized the most successful technical animation projects?**

This dissertation reviewed the approaches authors took towards the scaffolding of their technical animations, the perceptions of a range of audiences and a content analysis of each scaffolded project. Two projects in which the authors were not trained in Information Scaffolding, referred to as “unscaffolded projects”. The projects which had a limited number of message goals, goals which mapped to the comprehension questions and were well illustrated technically, had the highest comprehension and perception scores, and ranked highest in the content analysis.

During the *Intended Audience Survey 2009*, the lack of specification by the authors in illustrating the intended message goals could not hide. Three times survey participants commented that they felt the information asked for in the questions was not contained in the technical animation.

A major result of the *Intended Audience Survey 2009* showed a general underestimation of the participants, who were all members of one of the four intended audience options, and assumed to be intelligent non-experts of mechanical engineering. Based on the three sets of audience feedback, the projects which kept the big picture central and in focus, organized and supported the comprehension process and placed a premium on the clarity of understanding (well ranked projects: in terms of content analysis), did improve the audience understanding. The Transfer Case project, for example, had a viewer without prior knowledge of the device who, after viewing the project, had an understanding of the device’s purpose. The Digital Camera and Electric Drill had viewers with some prior knowledge, but who, after viewing the animation project, had a more detailed understanding of the respective device’s function. Both the Fishing Reel and Garden Leaf Blower projects had lower rankings and also had muddled viewer responses. Both of these projects had well written questions but did not present the necessary information well within the animations, the result being a set of misperceptions and misconceptions in the viewer responses. Finally, the Compound Bow project ranked highly in the content analysis, but the audience responses seemed to present confusion between the device’s sight and the stabilizer. A potential reason for this unexpected result is that the viewers were unfamiliar with this device whereas with comparable quality-wise (digital camera and electric drill) the viewers had prior knowledge to build upon.

After the Content Analysis conducted in Chapter 8, the technical animation projects were compared using the data evaluated throughout Chapters 6-8. Clear successes in regard to the three tenets of Information Scaffolding are the top ranked projects: the Compound Bow, the Electric Drill, the RC Helicopter, the Canon Digital SLR, the Transfer Case and the Boat Motor.

Table 14. Comparison of Top Ranked Projects

Project Title	content analysis total	content analysis comments	final technical grade (max 80)	perception scaffolding average	comprehension score	number of message goals
Compound Bow	8.8	concepts slightly abstract	76	0.96	0.83	10
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Canon Digital SLR	7.9		79	0.78	0.50	3
Transfer Case	7.7	assumes viewers know the purpose of a transfer case	76	0.76	0.83	3
Boat Motor	7.5	abstract	67	0.83	1	broad

The six projects listed in Table 14 (above) all scored highly during the content analysis and the final grade and the scaffolding perceptions. Where these six projects differ is in the comprehension scores and the number of attempted message goals.

The two projects which did not fair well in comprehension were the RC Helicopter and the Canon Digital SLR. The RC Helicopter had a single difficult question whereas the Canon Digital SLR had a low average comprehension score of 50 [how does the image actually get to your eye? (25), how does the lens focus? (75), what are the sounds that the camera makes and where do they come from? (50)]. The first of the Canon Digital SLR questions was oblique, the second was more concrete, and the third was specific to the particular model.

As for message goals, it is easy to say that authors are better off focusing on a few well-chosen message goals over many tangentially related ones. An investigation of these top ranking projects indicates that projects with a limited number of message goals that mapped well to the comprehension questions and which were well illustrated using animation, had the highest comprehension scores by fellow participants. The two projects which fared best in this respect were the Electric Drill and the Transfer Case.

## 2. What conclusions can be drawn about comprehension?

The types of questions written by authors ranged from very basic, almost trivial, as simple as multiple choice to well written and cleverly constructed (these type of questions represented a small majority). The former can be seen in the questions written by the authors of the Boat Motor and Garden Blower projects, the latter question type is well illustrated by the Folding Bike project.

For example, the Garden Leaf Blower Questions only listed five items in their concept inventory but the outlined principles of operation are focused and specific: *Air flow through device, electromagnetic functions of motor, transfer of power to fan, engaging power*. Then the three author-provided questions directly address the primary message goals. These questions can be considered a success in that the questions are audience appropriate, well stated, and inline with the project message goals.

Generally, comprehension challenges to the audiences were hindered first in that most questions did not indicate what depth of detail would qualify as a correct response. Secondly, audience members could not answer questions if the necessary information was not contained within the animation or was not presented in a manner which could allow the audience to register the information.

Again some examples of comprehension questions and responses were:

RC Helicopter:

Question: How does the swash plate movement affect rotor tilts?

Answer: tilts to change left/right direction.

Examples of an incorrect response are:

Floppy Disk Drive:

Question: How does the device read/write by magnetism?

Answer 1: by spinning the disk

Answer 2: light goes "pew" and writes

Answer 3: to be honest, the animation did not put enough focus for me to get it

Answer 4: don't know

Answer 5: by spinning the disk

Few substantive changes in comprehension were found during the Intended Audience Survey 2009. From reviewing the perceptions and comprehension of the *intended audience*, it is apparent that the intended audience members were primarily frustrated with the set up and framing of the animation projects.

Generally, these survey participants had strong instincts about how the devices worked in spite of being unfamiliar with the devices in particular. For example, a survey participant commented that she/he didn't personally fish, but nevertheless answered the comprehension questions correctly. The lack of specification by the authors in illustrating the intended message goals could not hide during the 2009 Intended Audience Survey. Three times participants commented following the animation that they felt the information asked in the question was not contained in the technical animation.

Both sets of comprehension scores show a need for authors to attempt to answer their own comprehension questions - a step which in fact may help to clarify the presentation of the message goals. The issue of comprehension is also muddled in that the authors are responsible for writing the comprehension questions. The failure of audiences to answer some questions may be the result of any combination of these issues as well as more obvious issues such as: poorly written questions, the necessary information not being contained within the animation or the use of vocabulary and terminology being inconsistent between the animation and the written questions.

Additionally, the participants in the 2010 technical animation critique were asked to list five functions or components of each device described in the technical animation, but overwhelmingly the participants listed components, with functions being an infrequent exception. Looking at the vocabulary, each project had a handful of descriptors which were used more frequently. Only the most high level describing terms were used – fuel tank, piston and handle as examples. This



becomes important to authors in two ways: 1. Should authors need or want their audience to know or learn unique vocabulary, they must find a way of introducing it. 2. This data helps to indicate what features the audience attended to while watching the animation. This may be, in part, the result of a bias towards prior knowledge of the vocabulary, meaning, listed parts were ones which the audience member had the vocabulary to describe. Nevertheless, this practice is an important one for identifying which features stick with an audience.

It is easy to argue that “everyday” authors are not teachers and are not responsible for what amounts to instructional design, but the inability of the survey participant to answer the comprehension questions is a clear indicator that the ‘point’ of the technical animation, as defined by the authors, is most often not coming through.

At a minimum, “everyday” authors of technical animation need to:

1. When it comes to information contained within the project, authors need to verify that the information is aligned with their message goals - is necessary information conveyed?
2. When writing questions, scaffold for the audience and define an acceptable answer including the level of detail.
3. The use of vocabulary needs to be consistent between the animation title, within the animation and comprehension questions.

### **3. Were the technical animation projects informed by the choice of audience and subsequent audience assessment in addressing the project message goals?**

All 19 technical animation projects did identify an intended audience and attempted, to varying degree, to let this intended audience inform the design on the technical animation project. OTHER was not given as an intended audience option. However, five projects chose to address audiences other than the four audience-types provided. Of those five projects, two projects identified general audiences and three identified specific audience.

The audience assessment portion of the Information Scaffolding Intervention was summarized in the written project supplement provided by the project authors. The brief assessment happened in two phases. The first portion of the written project scaffolding supplement was designed to help the project authors develop a brief but broad description of the intended audience.

The attempt to address the intended audience begins to break down at this phase. For individual projects, although most assumed a heterogeneous audience, there was little or no indication of what that means. For example, students could have specified at least two or three varying attributes within a specified audience, but there was no evidence of this in the written supplements. From the written project supplements, it is clear that most projects would ideally like the intended audience to both pause and replay the animation., although that’s an unlikely scenario.

Reviewing the written project supplements showed that most groups were very good at imagining an ideal scenario that they would have liked the intended audience to view and have access to the finished technical animation – many of these scenarios were both unrealistic/unlikely and not specific enough.

The authors both satisfied the assignment and attempted to answer the audience related questions as requested. The intention of the assignment was so they would have used the opportunity to couch the animation in more realistic scenarios. It is difficult for authors to define a realistic viewing scenario a priori and perhaps once a more realistic scenario presents itself the authors may have an easier time at ‘scaffolding’ or designing for the scenario and meet the user need.

Even for the spring 2008 animations the audience assessments could have been clearer, despite the instructional content being improved since the pilots in spring 2006 and the spring 2007.

Consider the five projects that selected OTHER as an intended audience. Of these five projects, two projects identified general audiences and three identified specific audiences. This is, to some degree, inappropriate to the exercise as it assumes an ingrained interest in the subject matter and some level of expertise. On the other hand, four of the five projects with Other audience types fared very well in the final grading and the established scaffolding measures.

An obvious conclusion is that it is difficult to design for a ‘general audience’. A recommendation would be to have a feedback cycle with the intended audience, during which time the authors would have an opportunity to question assumptions made about the intended audience or perhaps to get comprehension feedback on a draft of the finished product. As an example of an opportunity primed for a feedback cycle, consider this written statement from the Transfer Case Project.

*We suspect the audience already knows that four wheel drives are better in low traction situations. We don't think they've heard of a transfer case. They just want to know its purpose and how complex it is (likelihood of failure, for if they ever decide to buy a 4wd vehicle).*

The second phase of the audience assessment was to revisit the author-defined concept inventory, evaluating which of the items are assumed to be well known by the intended audience. This is to be the synthesis of the concept inventory and the audience assessment – and should be the basis for defining the project message goals. Only six of the 19 projects included this secondary step of mapping the audience demography to the concept inventory. The six projects that completed this step were: Floppy Drive, Fishing Reel, Electric Drill, Breadmaker, Vacuum, Playstation 2. Of these projects, three assumed that the intended audience knew all items in the concept inventory, defeating the point.

#### **4. Scaffolding Design Principles. What conclusions can be drawn from the implementation of the initial 7 Scaffolding Principles?**

Two of 19 groups attempted to address all 7 Scaffolding Principles while the remaining groups attempted to address some of the principles. These two projects, the Camera Lens and the Digital Camera, both received high final grades and high scaffolding principle averages, however, there were also projects that did not attempt to address all 7 principles and still scored highly. On average, the 19 projects attempted to address 4.58 scaffolding principles (rather four or five principles out of seven).

The six questions asked during the *fellow participant review 2008* were:

- 1 *Is the length appropriate? (Too long, too short, etc..)*
- 2 *Does the presentation approach and style help overall understanding?*
- 3 *Are there aspects of the animation that are overwhelming, distracting, or frustrating?*
- 4 *Weight & priority give to important aspects of device? Yes/no*
- 5 *Animation maintains big picture perspective while providing enough detail? Yes/No*
- 6 *Complementing media (good coordination of sound, motion, camera view, lighting). Yes/No*

For the *2009 intended audience survey*, participants were asked:

1. *Is the length appropriate? (Too short, A bit short, Just right, A bit long, Too long)*
2. *Does the presentation approach and style help overall understanding? (yes/no)*
3. *Are there aspects of the animation that are overwhelming, distracting, or frustrating? (yes/no)*

And for the *2010 technical animation critique*, participants were asked:

1. *Does this animation seem to provide a complete description of the device? In the same way an essay or presentation can seem complete or incomplete. From 1-5, 1-definitely missing information, 3-some additional information needed, 5-complete.*
2. *How many times would you need to watch this video in order to explain the assembly of this device? 1-10*
3. *How many times would you need to watch this video in order to explain the operation of this device? 1-10*
4. *Does the presentation style make the assembly and operation of the device memorable to you? Yes/No*
5. *List 5 functions or components of the device From the 2008 fellow participant survey the strongest significant correlations were between:*

The 2010 Technical Animation Critique indicated broadly that, the projects which received the intervention seemed more complete as well as more memorable (see survey result in Chapter 8)

Qualitative feedback from the 2009 intended audience survey provided important insight into some aspects of the audience's perceptions.

#### Length

Overall the length ratings tell this story: of the 20 responses 10 participants, or half, rated the length as *just right*. The Electric Drill Project at 5 minutes 36 seconds, received all *just right* responses. **No participant rated any project too short or a bit short.** Eight respondents rated the various projects *a bit too long*, and two of five participants found the *Camera Lens Project*, the longest project at 9 minutes and 55 seconds, *too long*.

Comments such as, *the animation went fast for confusing parts and slow for the parts that were obvious and regarding ... how a camera works, that information was really contained only in the last 2 minutes*, led to a suspicion that there are other aspects of time (tempo, priority), as well as in some manner the audience's expectations of the project's narrative (information metaphor or logic model), or even more simply the audience's grasp of the project's thesis, involved here. While what those factors

are cannot be determined from the available data, it is clear that for some, projects as short as 3 minutes and 40 seconds were perceived as too long.

#### Presentation Style

Having established the survey participants' instinctual perceptions of at least one aspect of the viewed animations - *length*, the next question looked to discover how the presentation approach struck the viewers. For this question participants were asked to provide a simple "yes" or "no", with an additional comment section not being provided.

With 20 responses, 18 affirmed that the *presentation approach and style helped overall understanding*. Only one person did not feel the *Camera Lens Project* was presented in a way that helped overall understanding, and one person felt this way about the *Garden Leaf Blower Project*.

#### Cognitive Overload

Cognitive Overload: Are there aspects of the animation that are overwhelming, distracting, or frustrating? 12 of the 20 respondents indicated some type of frustration or annoyance, although, in any animation it is easy to find some aspect of irritation. All of the cognitive overload section comments are listed below, most of which are specific rather than major indictments of the project's construction.

#### Comments:

- *Appears blurry in full screen mode.*
- *I felt like watching the entire camera being constructed was really long, whereas some of the animations in the last 2 minutes showing function were more enlightening*
- *The beginning 4 min of all the intricate parts being placed together - The initial explosion of parts just gets confusing -*
- *Background.*
- *The reorientation of parts once they are brought into the field of view seems unnecessary. the music is good, but distracting. it is blurry in full screen mode.*
- *I would have preferred a constant close up zoom for some of the mechanism scenes.*
- *The changing zoom was a bit irritating at times. Maybe I'm just in a bad mood.*
- *not a fan of the light pink background looks blurry in full screen mode.*
- *At times I felt like some components were made transparent when their presence would have helped me better understand what was going on.*
- *At the beginning, the point of reference was lost on the zooming in of groups of parts from the exploded view.*

During the 2008 *fellow participant review*, 34 students reviewed each of the 19 technical animation projects. The perceptions of each project by fellow participants was generally high, with two exceptions: the Beer Launching Fridge Project and the MOMO Force Feedback Wheel Project. The Beer Launching Fridge Project suffered in the perception of length (0.42) and the presence of cognitive overload (0.35) – the likely cause of this audience frustration was the project's 300 missing frames, which interrupted the narrative of the project, and left the project feeling short. The Force Feedback Wheel Project's low average score (0.55) can be attributed to low perception scores generally. The fellow participants did not respond favorably to this project and the project received low perceptual scores in all categories but length. Some comments provided by the review participants include: *Sound was grainy, lights were off, background was distracting, pace too slow, too short, ended without showing much operation*. Incidentally, these two projects received the second and third lowest grades based on the projects' technical requirements.

Correlations were found between some scaffolding principles

Table 15. Significant Scaffolding Principle Correlations

1 length						
2 presentation						
3 cognitive overload						
4 priority						
5 perspective		X		X		
6 complementary media				X	X	
	1 length	2 presentation	3 cognitive overload	4 priority	5 perspective	6 complementary media
grey'd boxes represent correlated principle and x's represent strong correlations						

The statistically significant correlation of scaffolding principles suggest a tiered consideration of scaffolding principles. The **Information Metaphor** should be a primary consideration in the organization and composition of a technical animation, with the **Information Priority, Use of Perspective** and **Complementing Media**, to be informed by this choice. Important questions to consider at the conclusion of the projects are:

1. Does the **Information Metaphor** hold throughout the animation?
2. Then do **Information Priority, Use of Perspective** and **Complementing Media** complement this metaphor or detract from it?
3. Finally, do the **Length** and presence of **Cognitive Noise** unnecessarily burden the audience or distract from the message goals?

RECOMMENDATIONS FOR TECHNICAL ANIMATIONS CONSTRUCTION	<p>Acknowledging that each type of document has its own set of communication challenges, there have been some lessons learned about the construction of technical animations which:</p> <ul style="list-style-type: none"> <li>- Keep the big picture central and in focus</li> <li>- Organize and support the comprehension process</li> <li>- Place a premium on clarity, clear direction and minimized confusion</li> </ul>
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Generally, technical animations should focus on a limited number of message goals which are well mapped to the comprehension questions and which are well illustrated using animation.

In addition to the a priori issues for technical animation addressed during the literature review, six considerations presented themselves as a result of this study:

1. Project Framing
2. Project Storyline
3. Time Design
4. Vocabulary & Nomenclature
5. Misperception & Misconception
6. Visual Distinction

**Project Framing:** The animation should be self-explanatory and stand on its own. Audiences, especially adult audiences, need to know the value of watching the animation is, and what they are expected to know coming out of it.

**Project Storyline:** If the audience can't follow the thesis of the presentation the audience will unlikely learn from the project. Does the presentation approach and style help overall understanding? We saw with the technical animation projects that the context of the assembly could have been better framed to give audience members a reason to be interested.

**Time Design:** Apportion time appropriately, revisit and revise as necessary. During the intended audience survey, a clear conflict arose between the project assignment (author motivation) and the audience motivation, illustrated by the audience frustration with the amount of time spent on device assembly. However, this is a realistic challenge of the authoring process – balancing the needs and motivations of both the audience and the authors, not one that should be considered insurmountable.

Recall that a major portion of learning is having the audience's attention, and that the author must budget the degree of attention required by the audience over the course of the viewing experience. The key distinction of animation is that time is an intrinsic property. Authors must leverage the use of length, tempo, pacing; asking: *Is the length appropriate? Does the audience have time to register (view and mentally process) key events?*

**Vocabulary: Nomenclature & Terminology:** Knowing that we all use different words to describe the same things, the use of vocabulary should be consistent between message goals, animation, and comprehension questions, and should be informed by the prior knowledge of the audience. The vocabulary you use will help those familiar with the terminology (for example: cams, servos, etc.) reduce the effort of confirming the use of these terms and for those unfamiliar with the terms: the use of nomenclature provides the words for what they are seeing. Without this, the audience may be floundering to find the words to describe what they are seeing - or at no point attempting to translate the information that they are taking in visually. The likelihood that this information will be committed to memory and learning achieved is unlikely.

**Misperception & Misconception:** Animations, simulations, and other dynamic media pose challenges to learning because there are opportunities for both easy misperception and misconception. Misperception can happen when the animation does not have the viewer's full attention but can also happen when the authors are careless about presenting key or logical steps or when the audience is not given time to register a series of key events. Misconception in animation most often happens when the visual information presented can be interpreted in multiple ways. For example, a ball rolling slowly down an incline may be due to friction, to slow computer processing, author choice, the presence of an oppositional force such as wind, or other causes. The lack of clarity by the author causes the audience to dismiss this issue rather than question it. The key in both cases is to not underestimate the visual astuteness of the audience, recognizing that frame for frame the animation is the window into how the content and its broader meaning should be viewed.

**Visual Distinction:** In the case of these technical animations, there are a number of visually generic parts. Authors should use distinctive parts to help audiences relate meaning to the purpose of the generic parts. Again, without purpose the generic parts will be dismissed or overlooked by the viewers and large portions of the animation ignored.

# 10 Future Research & Next Steps

NEXT STEPS FOR  
TECHNICAL  
ANIMATION  
RESEARCH

A number of avenues for future research present themselves. The natural extension is to follow through on the lessons learned from the 2008 Technical Animation Research Study.

How should these insights be integrated into the revised Information Scaffolding method? An author's checklist suggests itself.

The method should still begin with the learning primer and the authors should still create a concept inventory and conduct an audience assessment.

From here, authors should consider the application of some or all of the 7 scaffolding heuristics:

1. logic model/information metaphor
2. conceptual chunking
3. wayfinding and navigation
4. prioritization of key information
5. temporal and spatial relationships
6. complementary media

It may also be helpful, at this point, if authors identify what vocabulary and nomenclature is to be used and how:

Once a draft of an animation is complete, questions regarding,

1. Project Framing
2. Project Storyline
3. Time Design
4. Vocabulary & Nomenclature
5. Misperception & Misconception
6. Visual Distinction

should be asked in order to inform future project revisions.

The Design-Based Research methodology provides a conventional structure for reporting on experiments that evolved over time. This structure consists of four parts, and includes:

providing background to the problem,  
articulating the experimental method,  
providing results, and discussion.

To complete the DBR approach to this Information Scaffolding: Technical Animation Research Study a short meta-evaluation of the study's approach was conducted (this represents Step 5 of the five DBR steps:

1. Goals and elements of the design.
2. Settings where implemented.
3. Description of each phase.
4. Outcomes found.
5. Lessons learned.



“Considering what happened in the different implementations, the report should attempt to pull together all the findings into a coherent picture of how the design evolved in the different settings. It is important to describe the limitations and failings of the design, as well as the successes, both in implementation and outcomes.” [Barab ’04]

Table 16. Information Scaffolding Technical Animation Study Data Collection and Evaluations

Animation Projects [19]	Data	Extracted Data
	Digital hardcopy (CD or DVD)	Now available online
	Actual recorded length	3:21 to 10:27 (minutes and seconds)
	Final Project Grade	80 points possible
Written Project Supplement		
	Intended Audience(s)	4 suggested audiences
	Concept Inventory	4 -15 items per project
	Message Goals	
	Document Scaffolding Principles	
Fellow Participant Review 2008		
	Perceived intended audience	34 of 40 usable critiques
	Scaffolding Related Questions	<i>Is the length appropriate? Does the presentation approach and style help overall understanding? Are there aspects of the animation that are overwhelming, distracting or frustrating? Are weight and priority given to the important aspects of the device? Does the animation maintain a big picture perspective while providing enough detail? Complementing media?</i>
	Author Provided Comprehension Questions	
Intended Audience Survey 2009		
	Qualitative Analysis of ...	<i>Is the length appropriate? Does the presentation approach and style help overall understanding? Are there aspects of the animation that are overwhelming, distracting or frustrating?</i>
	Comprehension Question Responses	
Content Analysis		
	6 Metrics	Intended Concepts Framing Storyline Contextualization Vocabulary Part Registration
Audience Participation . Part 2		
	Audience Critique	complete description explain the assembly explain the operation presentation style functions or components of the device

Even after an emphasis on audience assessment during the 2008 iteration, the Information Scaffolding methodology still needed a set of more specific audience assessment tools. The analysis also showed that again and again the scaffolding process was less effective because the synthesis of the audience assessment and the document message goals did not occur.

The 7 scaffolding design principles have always been meant to serve as heuristics – general concepts through which authors might frame their use of media. No conclusions could be drawn after looking at the success of each project in conjunction with the number of design principles addressed. However, an important result is that the animation projects which scored highly in the perceptions by fellow students generally scored highly in each aspect of the scaffolding perceptions. This was independent of the number of principles the authors indicated using, where in some instances the project authors indicated addressing all of the principles and in other cases the authors indicated using only one or two. This suggests the presence of a gestalt, a conscious or unconscious understanding between group members regarding the selection and use of construction principles. This holistic effect was also validated by the correlation presented in Chapter 6.

The Content Analysis was informed by the results of Chapters 6 & 7. This chapter identified three new aspects for the content analysis, which are closely tied to key scaffolding design principles. These three new facets of the content analysis are: Storyline, Part Relationships and Registration.

The best projects from 2008 helped frame the content for the audience and communicated key mechanical elements, framing and structuring the purpose of these technical animations (scaffolded).

The research study outcomes revealed opportunities for iterative improvement of the 2008 version of the Information Scaffolding methodology. The next version of the methodology will include:

- a learning primer reading requirement,
- a revamped set of questions for the audience demography,
- a document mission statement of purpose,
- a more structured process for integrating the results of the concept inventory and audience assessment.

**LEARNING PRIMER REQUIRED READING:** So far the key learning elements relevant to technical animation construction have been presented only during the course lectures. However, in reviewing the 2008 projects, many did not have clear mappings between the intended message goals, the scaffolding process and the final product. There are examples of this in projects where the answers to the comprehension questions are not found within the technical animation. The short learning primer will be all of five pages long and could be easily supplemented with explicit technical animation examples.

**AUDIENCE DEMOGRAPHY:** The evaluation of the author-supplied written scaffolding supplements revealed that the authors had much difficulty picturing the audience perspectives, likely in part due to having never been in post-college working scenarios. A necessary improvement to the methodology would be a revision of the audience demography worksheet, in conjunction with better framing the value of addressing the audience's point-of-view. A major improvement necessary is the refinement of the audience assessment approach, including the development of a simple and effective list audience assessment questions – which will help authors sincerely evaluate the needs and prior knowledge of the audience.

**STATEMENT OF PURPOSE: CONTENT SELECTION & MESSAGE GOALS:** The inclusion of a statement of document purpose may serve to describe the author motivations and may provide a more accessible format for the authors.

**ACHIEVABLE MESSAGE GOALS.** The underlying belief seems to have been that for animation, if you can show it all, you've taught it all. However, during the review it seems that three or four intended message goals are appropriate for the length of these technical animations. The hope is that a statement of purpose might be a better way of addressing the document's aim in both scope and depth.

**CONCEPT INVENTORY & AUDIENCE ASSESSMENT SYNTHESIS:** the combination of the concept inventory and the audience demography was lacking in most groups. Authors need better tools for describing the intended audience, but they also need to follow the secondary step in translating the choices made during the audience demography to the concept inventory.

EXPANSION OF  
INFORMATION  
SCAFFOLDING  
METHODOLOGY

A second potential avenue of research would be to apply the Information Scaffolding methodology to another technical animation course or topic. The successes and difficulties of the scaffolding intervention in this particular class may be a unique combination of culture, discipline and prior knowledge.

TO OTHER  
FORMS

In another direction, the suggested technical animation principle suggestions could be compared and contrasted with other existing film and animation frameworks. What has been suggested are 7 design principles now along with additional frames through which to view the technical animations (see Chapter 8 Content Analysis). Future research could be directed at determining where commonalities lie with other animation production and assessment modes.

An aim of the information scaffolding methodology is to politely supplement and support an author's existing authoring process. Work has not been done yet to determine what aspects, if any, from the Information Scaffolding approach stay with the participants of an information scaffolding intervention during future animation projects. Degrees to which the intervention has an impact may vary widely ranging from seeing no connection to full implementation in future applications; others may see applications to technical or multimedia documents. The hypothesis is that much of this may be in how the scaffolding approach is framed. The optimal outcome would be for participants to find some relevance of the approach and compassion for audience-centered documents in all document construction.

The broadest potential direction and of the most current interest, would be to repurpose the 3-phase approach and apply it to other directions. Such other directions include the constructions of websites, presentations, or animations with a different project description.

# Back Matter

references

appendix 1. information scaffolding worksheet

appendix 2. CPHS protocol approval

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# Appendix 1. Information Scaffolding Worksheet (page 1 of 3)

DUE **May 12<sup>th</sup>**. email to: [kay@berkeley.edu](mailto:kay@berkeley.edu).

Date:5/12/08  
Group Name:  
Members Names:

ANIMATION TITLE:

Concept Inventory

The purpose of a concept inventory is to articulate a set of individual concepts that together describe the knowledge and information "contained" by the '*assembly and operation*' of your device. A concept inventory is a list of items including; principles of operation, background information, cultural relevance, and common misconceptions. The purpose of this exercise is to gain a detailed understanding of the knowledge contained in your device. Your concept inventory will not be complete in the sense that it covers everything, but is a brief synopsis of the concept, as you understand it.

NO	Concept Inventory:	YES
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

What principles of operation will be illustrated?

## Appendix 1. Information Scaffolding Worksheet (page 2 of 3)

DUE May 12<sup>th</sup>. email to: [kay@berkeley.edu](mailto:kay@berkeley.edu).

<p>Target/Intended Audience(s).          The purpose is to list some of the characteristics that describe your audience. Please Note: by targeting your audience this does not mean emphasizing the information most interesting to your audience but instead focusing on how the principles of operation are best expressed to your chosen audience.</p> <p>Electrical Engineers Material Scientists          Industrial Designers Business Decision Makers          College educated:</p>	
<p>Who is your target audience?          Is your audience homogenous or heterogeneous in;          .background education?          .prior knowledge?          .professional experience?          .relevant cultural experience?</p>	
<p>POPULATION SIZE          Initially and over time how many people will watch your animation?</p>	
<p>MOTIVATION          Foremost, why is the audience interested in your document? What are their goals?</p>	
<p>CONTEXT          Where and when will the audience have access to your animation? Will they be able to view the animation only once or repeatedly? Will they be able to pause or will they be watching the animation straight through? Are they familiar with the presentation style and format?</p>	
<p>CONTENT          What do you suspect the audience already knows? What does the audience expect to walk away with? And with how much detail and significance? Give an example of how they will use this information in a new situation.</p>	

# Appendix 1. Information Scaffolding Worksheet (page 3 of 3)

DUE May 12<sup>th</sup>. email to: [kay@berkeley.edu](mailto:kay@berkeley.edu).

List 3 questions regarding the principles of operation that an audience member should be able to answer after watching your animation?

## Scaffolding

### Animation Specific Scaffolding Principles

Describe briefly the approach your group has taken in constructing your animation, including the scaffolding principles you are employing.

Check All That Apply

◊-Information Metaphor

. through line from beginning to end.

◊-Conceptual Chunking/Information Density

. breaking up information appropriately based on audience.

◊-Wayfinding & Navigating

. getting audience from beginning to end and keeping them with you along the way.

◊-Prioritization of Key Information

. consciously showing how much information, why and when. Not giving equal weight to all aspect of the device, prioritizing key elements

◊ Temporal & Spatial Relationships

. maintaining relationships between pieces of information, objects and sub-assemblies over time.

◊-Global and Local Perspectives

. global and local perspectives used when necessary.

◊-Complementary Media

. music, motion, lights, cameras, etc complement animation.

Explanation

# Appendix 2 . CPHS APPROVAL

UNIVERSITY OF CALIFORNIA AT BERKELEY

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January 30, 2009

CATHERINE NEWMAN (kay@berkeley.edu)  
Mechanical Engineering  
6102 Etcheverry Hall MC# 1740  
Berkeley, CA 94720-1740

RE: **CPHS Protocol #2006-2-36**  
“Multimedia Document Scaffolding” - Graduate Research - Mechanical Engineering

Dear Ms. NEWMAN:

Thank you for submitting a request for approval of amendment to the above-referenced protocol. On 1/29/2009 the following amendments were reviewed and approved on an expedited basis under expedited review category 45 CFR 46.110 (b)(2):

1. Add subject group for final phase: recruit up to 40 professional electrical engineers, material scientists, business decision makers and industrial designers to watch the animations constructed earlier in this study to assess the quality of the animations.

The number of this approval remains **2006-2-36**. Please refer to this number in all future correspondence about the project. **The expiration date of the approval also remains 4/15/2009.**

Please note the following:

The attached stamped, approved consent materials must be used for the consenting of any new subjects.

*Continuation/Renewal:* Approximately 8 weeks before the expiration of this approval, OPHS will send you a courtesy reminder. Applications for continuation review should be submitted no later than 6 weeks prior to the expiration date of the current approval to allow sufficient time for the renewal process. *Note: It is the responsibility of the Lead Investigator to submit for renewed approval in a timely manner.* In keeping with federal regulations, *if approval expires, all research activity (including data analysis) must cease until re-approval from CPHS has been received.* Before applying, please check current CPHS guidelines, instructions and forms available at <http://cphs.berkeley.edu>.

*Amendments/Modifications:* Any change in the design, conduct, or key personnel of this research must be approved by the CPHS *prior* to implementation. (For more information, see “[Process for Submission & Review of Applications](#)” and “[Application Forms & Informed Consent](#)” on CPHS website).

*Unanticipated Problems and Adverse Events:* If any study subject experiences an unanticipated problem involving risks to subjects or others, and/or a serious adverse event, the CPHS must be informed *promptly* within no more than *one week* (7 calendar days), and receive a written report within no more than *two weeks* (14 calendar days), of recognition/ notification of the event. (For more information on definitions and reporting requirements related to this topic, see “[Adverse Event and Unanticipated Problem Reporting](#)” on the CPHS website).