Comprehension Scaffolding for Multimedia: Structuring Technical Animations for Learning

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A B S T R A C T- *Engineers are a part of a growing community of everyday multimedia information-documenteurs, including professionals, academics, artists and educators. For members of this cross-disciplinary community understanding by every audience can no longer be assumed, and the burden of learning can no longer placed entirely on the user. In the case of technical animations, where the purpose is to extract technical information: simple design principles can add a meta-cognitive structure to improve comprehension by a range of audiences. In the field of education, the structuring of information for learning is called scaffolding. Some of these scaffolding principles have been informally discovered and implemented by mechanical engineering students in the course-Advanced Engineering Graphical Communication, taught at the University of California, Berkeley. This paper synthesizes research from education, cognitive science, and design to formalize principles for the improved comprehension of technical animations.*

In this paper design principles and an accompanying methodology are presented. Key terms and definitions are presented to ground the methodology and principles that follow. Background research is then provided to establish the foundations of the proposed methodology. To conclude, the 7-step methodology is presented, included in which are design principles and additional supporting research.

I. INTRODUCTION

Animations for entertainment are familiar to all of us, and while animations for technical communication are commonplace for many of today's engineers, they have the opportunity to be more instructive for both the engineers and non-engineers who view them.

Technical animations serve a purpose beyond entertainment they communicate and inform an audience of an object's mechanical workings and inter-part relationships of objects in context.

Research indicates that multimedia information can reach a wide range of learning types, if used properly. The aim of this paper is to encourage the creators of technical animations, to consider technical animations as learning artifacts that are intended to contribute to a wider knowledge community.

This paper seeks to address the question: how can technical animations provide an opportunity for learning without increasing the burden of creating a final product that is attractive, accessible, and compelling?

Proposed in this paper is an approach to presenting technical animations that allows engineering students to embed, frame and facilitate the comprehension of their work.

Created using established research principles from cognitive science, education and instructional design, this method is designed to add a structured meta-cognitive layer to technical animations. In the field of education, the structuring of information for learning is called *scaffolding*.

In this paper design principles and an accompanying methodology are presented. Key terms and definitions are presented to ground the methodology and principles that follow. Background research is then provided to establish the foundations of the proposed methodology. To conclude, the 7-step methodology is presented, included in which are design principles and additional supporting research.

II. KEY TERMS

Scaffolding

Developed in the field of education, *scaffolding* is a technique for improved learning used to facilitate the comprehension of information by a range of users, both inside and out of an information domain. Scaffolding is:

-conscious consideration given to the user's abilities, needs, and values, as well as the conventions of the medium and knowledge domain.

The scaffolding of information should be a consistent enactment of these considerations.
Scaffolding should:
-keep the "big picture" central and in focus
-organize and support the comprehension process

-place a premium on clarity, clear directions, and minimizing confusion.

[Adapted from-McK '99]

Comprehension

Comprehension is often used as a synonym for understanding and has many definitions. For the purposes of this paper, and its related research comprehension will be defined as-

-a deep understanding of the presented information, which includes; attending to important aspects of the material, mentally organizing it into a coherent cognitive structure, and integrated it with relevant existing knowledge for the potential of later use.

[Adapted from-Mayer '03]

The comprehension of technical animation is influenced by the additional embedded factors:

-Temporal and Spatial Relationships
-Medium and Information Affordances
-Conventions and Consistency

[Hartley '94] [Kolers '73]

These factors allow users to differentiate between the relevant and irrelevant information, and prioritize new or novel information [Park '83]. These processes are fundamental pre-steps to comprehension.

The embodiment of information into a message can be done using a combination of visual (depictive/images) & textual (descriptive/text) information. Depending on the message content, some combinations images and text will be more effective than others.

Additionally each message carries with it un-expressed or implied information, which will play a role in the comprehension of an author's message. Key examples of this type of information are: the author's prior domain knowledge, and the tacit relationships between sub-sections of information and their relationship to the larger message.

Cognitive Overload & Cognitive Noise

Attempting to understand a multimedia message requires 3 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

3. *Representational Holding* - the effort required or necessitated in holding a mental representation in working memory over a period of time.

[Mayer '03]

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]*)* **Cognitive Overload** presents a very real barrier to comprehension.

Minimizing the aspects of a message that over tax the types cognition listed above (known as **Cognitive Noise**) can reduce unnecessary **Cognitive Overload**. Cognitive Noise often occurs in technical animations when either; the information being presented in 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, audio).

Common forms of **Cognitive Noise** in 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
- Lighting too dark or too light
- Overly cluttered environment

III. KEY MULTIMEDIA RESEARCH: IMPLICATIONS FOR ANIMATION

Schnotz (2001) 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”. However 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, which could benefit from way-finding or narrative cues, designed to identify how the author wishes the presented information to be traversed and processed.

Animations are extremely helpful for comprehension 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]

Research has shown that dynamic representations that users can manipulate are superior to animations (and far better than static representation) because they lead to a better encoding of detailed information by the user. The result is that the user is able to maintain a stronger, more stable representation of the presented information. Because the opportunity for the manipulation of technical animations is rare, authors should provide opportunities for implied manipulation and reflection throughout an animation.

Duke & Pearson (2002) emphasize that in addition to the rudimentary transactional cognitive processing of information, audience members are making judgments (i.e. value, quality, etc) about the information, in addition to bringing unique prior knowledge, and individual learning techniques to the experience. If animations are to be transformed into learning objects, it is imperative that the learning needs and style of the audience be addressed.

SCAFFOLDING METHODOLOGY

4 factors play apart into the presentation of information: Message, Medium, Author and Audience.

The transfer of information is taken from author to audience, through a message that is housed in a tangible medium. (e.g. computer screen or paper)

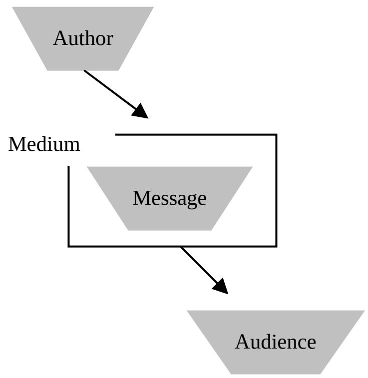

Fig 1. Information Diagram

Scaffolding Methodology.

Step1. Understand Users’ Information Needs and Values

Step 2. Identify Key Message Goals

Step 3. Identify Overarching Metaphor Or Logic Model

Step 4. Use Scaffolding To Support Key Message Goals

Step 5. Reconsider Message Elements That Add Cognitive Noise

Step 6. Get Feedback From Likely Audience Members

Step 7. Revisit Steps 1-6 As Necessary

SCAFFOLDING METHODOLOGY

Step1. Users' Information Needs and Values

Key points of audience demographic are:

- What are audience's reasons for viewing the animation?
- Does the audience have familiarity with animation topic or information domain?
- Does the animation serve as the primary or secondary information source?
- Will the audience have the ability to replay or revisit animation?
- What is the external context for the animation (classroom, work, etc)?

Step 2. Identify Key Message Goals

a. Animation goals b. Audience goals

c. Author goals d. Learning goals

Key points of message goals are:

- How are goals of the author and the audience similar or different? Are they mutual exclusive?
- How can the animation goals (i.e. quality) complement the learning goals (i.e. clarity)?

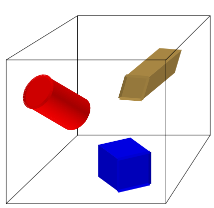

Fig. 2a. The location of an object affects the overall-balance, composition, and perception of the animation volume or 3D space.

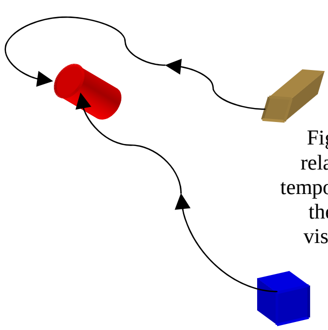

Fig 2b. What are the relative relationships between objects, temporally and spatially? How can the use of color, orientation, visibility and weight enhance these relationships?

Step 3. Overarching Metaphor or Logic Model

Key informational structure questions:

- How will in the information be presented & why?
- How does this structure support both the audience and learning goals?

General examples of a technical-animation structure include…

- Order of assembly
- Direction of action or use
- Simplest subassembly to most complex

Step 4. Use Scaffolding to Support Goals

"[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" [pg. 208-IMD '93]

Authors can facilitate the comprehension process by appropriately chucking the information into digestible pieces and by presenting those pieces into the larger organized representation. Visual artists frequently apply the concepts listed to the right.

Consider applying the artistic concepts listed in table-1, to the 3 dimensions of animation described below.

_Balance
_Color
_Composition
_Coordination
_Depth & Detail
_Intensity
_Layering
_Orientation
_Placement
_Repetition
_Scene Length
_Synchronizing
_Timing
_Visibility
_Weight

Table 1. Visual Grammar

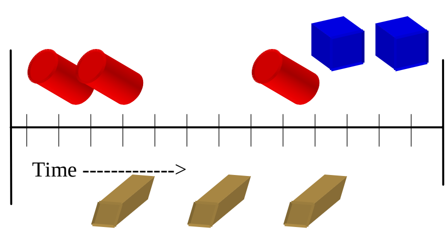

Fig 2c. What is the overall story or trajectory of an object or objects over the Animation Timeline? Does this trajectory align with the overall animation metaphor? Could the animation benefit from use of repetition, synchronicity, or a reordering of scenes?

SEMANTIC COHERENCE

Strive for a shared understanding between the author and audience at key information points in places where understanding is essential for continued involvement by audience members.

For the animation of this M1 rifle (fig. 3) the authors introduced each scene by framing the beginning of each subassembly with a title.

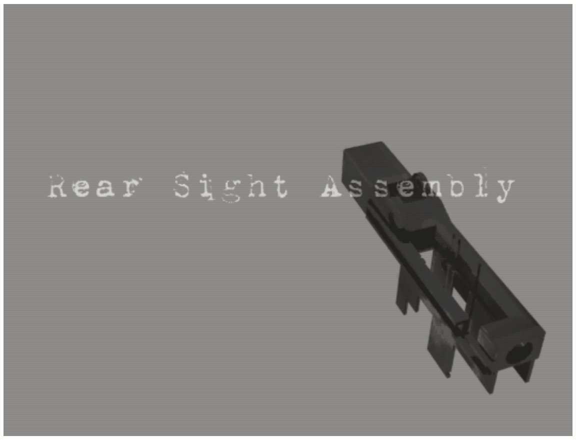

Fig 3.
Titles used by author to frame animation

REFERENTIAL LINKING

Making explicit or implicit links between logically related elements provides opportunity for alignment between author's intent and audience interpretation. Linking is one way to improve Semantic Coherence.

Fig 4.
In the case of the paintball gun pictured above, 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 simple an understanding of how all of the parts came together but insight into the cause and effect relationships within the device worked once the pieces were assembled.

ORDER MATTERS

Information is processed and remembered in "chunks". A message's structure determines how chunks are formed the viewer and how memory for the message is organized. Logically organized information will "facilitate flow between short and long term memory" [IMD '93]

The KULESHOV EFFECT

Lev Kuleshov was an early Russian filmmaker who believed that juxtaposing two unrelated images could convey a separate meaning. In the Kuleshov experiment he filmed 5 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 suggested by the order in which the shots were presented [LevK]

Fig. 5.
This disassembled chainsaw contains over 250 unique parts. The order in which the subassemblies are presented will make a large difference in the understanding of the assembly and use of a chainsaw.

PRIORITIZE & WEIGHT

The processing of information is aided when emphasis is used to differentiate objects or information chunk. Framing a primary object and using neighboring parts to complement can help to give importance or weight.

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Fig 6.

In this example, the authors zoomed in to highlight the unique motion of the cross-shaped button relative to the larger assembly.

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.*

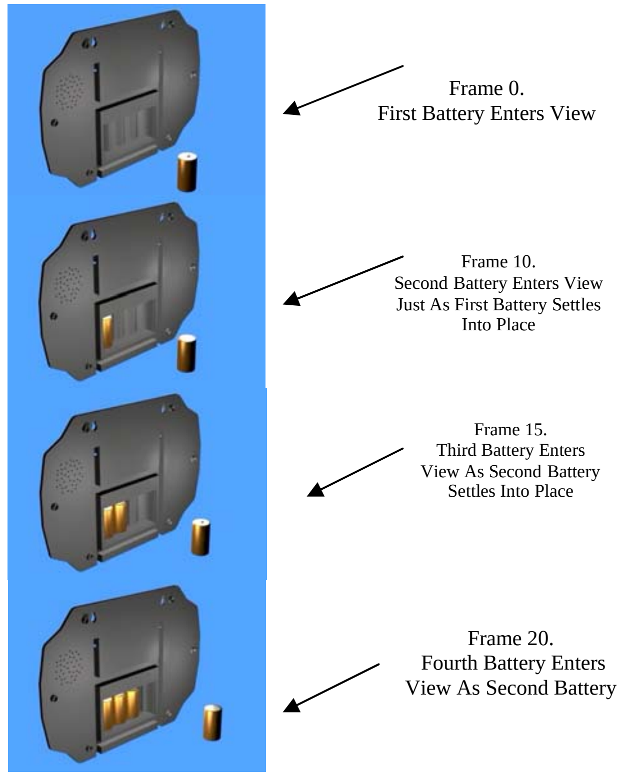

Fig 7.

This device contains 4 batteries. The animation of the batteries is done is 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 4 batteries are all the same and that all 4 batteries are necessary for operation. If all of the batteries were to enter at once this information could be potentially glossed over and if too much time were taken adding each battery the viewer may lose interest.

Step 5. Reconsider Message Elements That Add Cognitive Noise. Cognitive Noise is common in situations when,

-The information being presented is complex and thus requires a lot information to be presented at once.

OR

- Extraneous information is present in one or more of the available modalities (visual, textual, audio).

For complex or detailed information consider,

Off-Loading-moving information to other modalities-text (annotation) or audio (narration or sound cues). Caution- 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]

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

Pre-training-introduce part and component names and characteristics before hand to familiarize users with building blocks.

If an animation is overwhelming or confusing consider,

Weeding-eliminate unnecessary material, particularly material that however interesting, is unessential.

Signaling-provide cues for way-finding or traversing material (narration, sound cues or visual signposts)

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

Synchronizing-synchronize or align actions to minimize the need for representational holding by audience members.

Step 6. GET FEEDBACK. An outside perspective is especially helpful in understanding what is clear and what is coming across in an animation.

Step 7. Use feedback from audience members to improve animation with respect to the goals identified in step 2. Revisit steps 1-6 as necessary.

IV. CONCLUSIONS

The 7-step methodology for improved comprehension of technical animation that has been presented can be used to supplement current engineering graphics communication curricula with the intent of improving the level of information takeaway from technical animations.

Some of the scaffolding principles discussed in this paper have already been informally discovered and implemented by mechanical engineering students in the course-*Advanced Engineering Graphical Communication*, taught at the University of California, Berkeley. Having formalized a methodology and scaffolding principles for the improved comprehension of technical animations, the next step is to supplement a current technical graphics curriculum with this approach, providing an opportunity for students to practice art of communication for learning

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Animation Credits.
Fig 3. M1 Rifle. Mark Moyes, Laurence Paik. Anthony Tedesco

Fig 4. Paintball Gun. Authors Unknown.

Fig 5.Chainsaw. Andrew McGraw. Brad Crooks. Steve Hodson

Fig 6. PS2 Controller. Katherine deGuia. Francisco Valdez. Michael Venegas

Fig 7. Big Mouth Billy Bass. Claire Hunter. Stanley Lin. Catherine Newman