A Practitioner's Guide to the Design of Science Animations

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Abstract: *The assimilation of complex transient information is limited by the learners cognitive processing ability and their level of prior knowledge. As such it is incumbent on educators and instructional designers to be familiar with evidence based guidelines in the field of multimedia learning and also to be cognizant of the pivotal role undertaken by the learner when interacting with the learning task. Establishing the layout of the material, adjusting the intrinsic difficulty of the task and ensuring that the learner interacts with the subject matter in a productive manner are the key factors to improving student learning by instructional animations and film clips. The present paper presents a practical guide to recognizing and implementing good practice in the design of science animations and film clips.*
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1. Introduction

Using animations and film clips for teaching science has several advantages: they can illustrate extremes in speed and scale and they are cost-effective because they are re-usable and easily disseminated. However, instructional animations remain inherently problematic in that they require the learner to simultaneously retain past, present and upcoming elements of fleeting information so as to enable integration and encoding of knowledge. There is a tendency for such intense processing to overstretch the limited working memory resources, and thus impede meaningful learning (Sweller, Ayres, & Kalyuga, 2011). Nevertheless there remains an ongoing acknowledgement that certain types of information, such as found in science, are best represented through animations and film clips (Betrancourt, 2005).

2. Designing the Layout and Presentation of the Learning Material

To avoid overwhelming the learner's cognitive resources entails the combined efforts of the instructional designer, the educator and the learner. Their respective roles, not always clearly delineated in practice, can include:

1. **The instructional designer**, with the aid of the educator, should ensure that the layout and presentation of the animations facilitates the assimilation of the complex information.
2. **The educator** should consider the complexity of the learning task relative to the student's level of prior knowledge and adjust the intrinsic difficulty of the subject material in order to ensure a type of optimal balance between task and learner.
3. **The learner** should be able to utilize the learner-control mechanism to ensure that the pace and sequencing of the information aligns with their processing abilities and level of prior knowledge.

2.1 Determining the Layout and Presentation of the Learning Material

Educational psychologists have formulated a number of cognitive design principles regarding the layout and presentation of dynamic information (Mayer, 2008). Many of these evidence-based guidelines help to ensure that the learner:

1. focusses their attention on the critical aspects of the visualisations. This "signaling" effect is often achieved through the use of labels, arrows and highlighting/fading techniques.
2. can integrate the information easily. This might be achieved by co-locating visual elements that need to be integrated and thus avoiding a "split-attention" effect.

3. optimizes the use of both modalities. If the description of the animation was in a text format the learner would have to split their visual attention between reading the text and viewing the animation. By offloading the text to a synchronised audio narration, the designer effectively engages both modalities in order to more efficiently facilitate the integration of otherwise disparate sources of information.
4. is not asked to assimilate information that is superfluous to the task at hand. By omitting decorative elements and redundant information the designer can assist in promoting an efficient learning scenario.

2.2 Adjusting the Intrinsic Difficulty of the Learning Task

Usually, the educator has a mastery of the learning material and a familiarity with the general level of prior knowledge amongst the learners. Consequently he/she is ideally placed to ascertain whether the novelty and complexity of the task is likely to overwhelm the cognitive resources of the students. The educator can take various measures to decrease the cognitive load placed upon the learner by:

1. segmenting the information into conceptually discrete "portions" to allow the learner to understand the organization of the material and also to "take a breath" between segments in order to digest the information.
2. just providing the "skeleton" of the task initially. Referred to as "isolated element interactivity" by educational psychologists, this involves providing the key elements first so that the learner may create a framework or "scheme" upon which to understand the fuller, more complex, version of the material.
3. providing worked examples. Where scientific animations explain formulas and problem solving procedures, it is often recommended to expose novices to a number of worked examples prior to setting problem-solving tasks.

2.3 Learner control and the role of the student

Despite the best efforts of designer and educator, the pivotal role of learning with complex instructional animations and film clips often rests with the learner. Through the use of learner control mechanisms the student can tailor the pace and sequencing of the presentation to befit their own spectrum of prior knowledge. Pausing and/or rehearsal of difficult sections can be balanced with less attention and time spent on sections with which the learner is already familiar. Investigations by the authors into student learning reveals that often they fail to capitalize on the control and flexibility that is afforded to them by learner control mechanisms. One procedure to ameliorate this shortfall is to provide explicit instructional advice regarding the optimal use of the learner control mechanism to tailor the presentation to fit their own cognitive abilities and specific learning requirements (Hatsidimitris, G., & Kalyuga, S. in press).

3. Room for Creativity and Innovation

Many of the guidelines and principles forwarded in the paper emanate from research findings. However, the results are not always replicated and many aspects of multimedia learning have yet to be investigated. Whilst the literature refers to ongoing debates concerning still versus animations, the authors have viewed the issue of dynamic versus static quite differently. Often, stills from an animation have been designed to be shown in a step-like fashion because the learning task was amenable to this style of pacing. Also, the use of a timeline scrollbar by the authors, as a form of learner control that can slow down animations to a set of stills, further blurs the boundary between stills and animations (See http://www.animations.physclips.unsw.edu.au). On another issue relating to the debate as to whether animations and film clips are qualitatively different, the authors have regularly utilized animations in conjunction with, or as overlays, to film clips. This is particularly effective in assisting the novice to view underlying scientific principles/phenomena with the trained eye of an expert. Our approach has been to consider guidelines and to respect them in most cases, but to violate them in some cases where user feedback and experience suggest it.

We present some examples of implementation of the guidelines (and some of their violation) on www.animations.physics.unsw.edu.au/educational-animations/ & http://www.animations.physclips.unsw.edu.au

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