# Attribute Activation:

# An Approach for Learning Visual Representation

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## Abstract

This paper will present an instructional approach entitled, "Attribute Activation" for creating and understanding visual representations. This is a technique based on cognitive theory. It will facilitate the construction and critique of visual images by slowing students down to be systematic. This instructional approach will encourage students to identify the important elements of a portrayal and understand how meaning is constructed. This document includes a literature review that explores the power of visual literacy for learning, a brief exploration of individual differences in visual processing, visual selectivity, visual problem solving, and attribute activation theory. It goes on to describe how new media and technology can be used to enhance the Attribute Activation technique. Finally, the implications for visual education will be discussed.

Keywords: visual learning, visual representation, visual critique, visual design, visual construction

## 1 Introduction

The pedagogy for learning and understanding language is a topic that is considered commonplace. Language Arts is a standard part of primary and secondary curriculums and is often a necessary component of post secondary programs. When it comes to the concept of communication, Language Arts gets much of the attention, and this is how it should be. However, the art and science of communicating with images often gets short shrift. While the topic of Art is often part of the primary curriculum, it is relegated to an option in secondary education and as a specialty in post secondary education. The topic of graphical communication is often relegated to Art courses and those who have a flare for it. In other disciplines visual forms of communication are rarely given consideration beyond viewing a textbook diagram or an overhead illustration. Graphical critique, understanding, and design are rarely discussed.

Given the ubiquitous nature and effectiveness of visual forms, it is the contention of his paper that students need strategies for evaluating and designing graphical forms of communication. Since the grammar and syntax of visual communication is not well articulated how can one approach teaching such important skills?

The purpose of this paper is to introduce a generic approach that can be used by instructors to help students become more critical of visual representations and able to design effective graphical representations.

## 2 Power of Visual Literacy

Human experience with the world often has visual spatial dimensions and the mind has learned to orient itself and understand that aspect of the environment. Visual portrayals can take advantage of those experiences and facilitate unique ways of learning and communicating.

The 20th century philosopher Ludwig Wittgenstein [1967] raised a question that seems pertinent to this study: "How do I know what I think until I see what I say?" Wittgenstein was referring to written language and the power it has to mediate understanding. Without it, he questions whether he knows what he thinks. Will graphic forms provide the same kind of benefit? Can visual images help us think?

Effective visualizations may achieve the following educational benefits:

- ask questions
- see patterns
- make inferences beyond the information collected
- identify changes over time among variables
- make a persuasive case in rhetorical situations; to get others to see what you see clearly
- open up lateral thinking by allowing broad interpretation
- expression of opinion
- creative outlet
- help answer questions
- attract attention
- provide an avenue to question and investigate a topic
- discover details of understanding
- address the needs of those who are visually inclined
- provide an alternative mode of communication or expression
- break a complex process down into bite sized chunks
- visualize new relationships
- make an idea more obvious and make ideas less ambiguous
- facilitate the recall of ideas
- simplify the complex - e.g. make the steps more concrete and immediately apparent
- increase access and circumvent language issues
- organize concepts or ideas
- make the abstract, understandable
- enhance way-finding (maps)
- make spatial relationships clearer than language
- provide a visceral or direct communication with the senses and emotions
- link to other ways of knowing
- create an atmosphere or mood
- illustrate the organization and relationships between concepts
- explain how to use something
- demonstrate what things look like in the present, past, or future
- provide warnings
- triangulate understanding (one of multiple representations)
- communicate kinesthetic activities

Visualization has long been noted as a significant tool in many problem-solving situations. Rieber [1995] lists great scientists that tackled difficult problems with the help of imagery, like Einstien's theory of relativity, Kekulé's molecular structures of benzene, Faraday's lines of magnetism, Snyder's containment of uranium, Watson's double helix, Feynman's quantum electrodynamics, John Snow's plotting of cholera deaths, and the list goes on. Einstein indicated that he rarely thought in words. These individuals used visual imagery to solve difficult problems. It is interesting to note that most of those visual skills are not attributable to school learning. Education on the whole is less likely to accept a visual portrayal than a verbal or written argument. For instance, educators typically use reports, essays, short answers, and multiple choice questions for assessing student understanding. Graphical constructions are rarely encouraged. What complicates this is that, some individuals are naturally attuned to the visual so to deny them a graphical avenue of expression could be doing them a disservice.

The concept of visual literacy suggests that there are a set of visual skills that can facilitate thought and communication. Flattley [n.d.] suggests that there are ideas that have to be seen, to be understood. The following phrase from Spiro & Jehng [1990] seems to capture one of the important concepts behind this paper: "Knowledge that will be used in many different ways has to be represented in many different ways, with the potential to form various combinations." (p. 203) Visual forms of portrayal provide unique ways of seeing and communicating ideas. Kozma [1991] notes that the use of different visual systems activates different cognitive representations and processes which can lead to the unique integration of knowledge.

Textual representations often fail to adequately account for nonverbal and nonlinear ideas. Math literacy, language literacy, and technology literacy are common frames of reference. The assumption in all these frameworks is that those skills can be learned and developed. Is this assumption true for visual skills? There are individuals who feel that this is true yet this gets short shrift in our educational system. Verbal and textual forms of communication dominate formal schooling. Fine-tuning grammatical structures, memorizing spelling, and practicing verbal communication skills consume student time. These are important skills to develop. However, visual-spatial forms of expression require new skills and critical perspectives, which need to be encouraged through visual learning experiences.

One benefit of visual representations is that these can alter cognitive frameworks and this in turn influences learning. In other words, if visual portrayals can modify activated knowledge structures then learning will be altered. There is evidence for this in experiments that involve the recall of objects. For instance, it has been found that learners who have visual organizational strategies perform better than those who don't [Kuhn, 1984]. To provide more support for the use of visual representations, Levie and Lentz [Levi & Lentz, 1982] provided a comprehensive metaevaluation on the effect of illustrated texts on learning. They summarized the results of 155 studies of learning from illustrated versus non-illustrated text. Forty-six of those studies involved a comparison between learning from illustrated text material versus from text alone, in comprehension and retrieval studies. "In all but 1 of these 46 cases, the group mean for those reading illustrated text was superior to that of the group reading text alone. In 39 of the 46 comparisons, the difference was statistically significant and the average group score for the illustrated-text group was 36% better than for text-alone groups (p. 198)." More recently, studies by Kargopoulos, Bablekou, Gonida, and Kiosseoglou [2003] as well as, the study by Hart and O'Shanick [1993], found that pictures are more effective than other types of formats in improving memory retention. Mayer [Richard E. Mayer, 2001] reported that visual representations generally enhance the recall of information over a series of studies but with some caveats that competing channels of information can negatively impact learning. This would tend to support the notion that visual portrayals activate a richer number of connections, which in turn has ramifications for learning. Visual forms of expression can be valuable for thinking, learning, and problem solving.

There is little formal instruction in schooling on how to construct or decode graphic forms. However, there is evidence to suggest that we can improve these skills with practice [Arnheim, 1974]. Olson [1985] has argued that education is biased toward verbal versus graphic forms of communication. The reasons for this condition may be a cyclic one. A lack of instruction about graphical forms, results in students who lack graphical expressive skills. These students develop into teachers who, in turn, lack graphical instructional skills. So the cycle continues. Students are not learning how to deal with graphical forms of portrayal so they are ill prepared to make interpretations on graphical portrayals. Taylor and Cunniff [1987] contend that for certain applications, graphic portrayal of concepts is superior to textual portrayals, at least for some learners. This argument does not suggest doing away with textual or print materials; rather the graphical aspects enrich a student's understanding. Papert [Weir, 1987] states, "Individuals can -- and in some cases must -- follow very different learning paths" and "Some children are crippled by mismatch with the intellectual style of the curriculum". Speaking of the children described in Weir's book, Papert goes on to say "her prime example of mismatched learners is the category of spatial thinkers -- children who can achieve a high quality of intellectual work when they are allowed to use more spatial ways of thinking..." [Weir, 1987], page x-xi, Forward]. Winn [Winn, 1987] indicated that portrayal tools give a graphic advantage by influencing the form of expression and how that information gets processed. Spatial tools provide learners opportunities to take advantage of spatial cognition.

Representational artifacts have a power to help us think [Latour, 1986]. Visual artifacts are portrayals that enhance thought by either increasing its capacity by off loading memory, or activating critical thinking processes. Visuals are often simplification or representational, so as transformations or insights are made, then the mind can go back and relate that to the referent. This alleviates cognitive load and frees the mind to focus on higher order processing. Vekiri [2002] reports that research into visual representations suggests those are more effective when they free up cognitive processing. In a sense, visual artifacts can make us smart. Norman [1993], in his book, Things that Make us Smart, suggests: "The power of the unaided mind is highly overrated" (p. 43). Without external aids, thinking is constrained. Norman suggests that external aids can enhance cognitive abilities.

Another concept is that of "visual argument" which suggests that visual portrayals provide an affordance because there are fewer transformations needed to take place in the mind. There is a gestalt because perception can bring the image into the mind without overwhelming working memory [Vekiri, 2002]. The mind can envision graphical relations and implications at a glance rather than the sequential processing required by language.

Multiple visual representations may have unique benefits. This is often referred to as multimedia. Multimedia is a form of communication that deserves more attention in our educational system [Daley, 2003; Steed, 2001]. The other aspect of multimedia is that it often involves students constructing portrayals, so is of interest here. Daley [2003] suggests that visual literacy is more than being able to read visual forms but should include the concept of creation. She states the following in regards to creating multimedia:

"Such principles as screen direction, the placement of objects in the frame, color choices, morphing, cuts, and dissolves all do

much more than make a screen communication aesthetically pleasing. They are as critical to the creation of meaning as adverbs, adjectives, paragraphs, periods, analogies, and metaphors are to text. Multimedia also requires that attention be paid to design, navigation, and interface construction. ...we are committed to empowering faculty and students to choose the best language for the task at hand. In some cases, this language may well be linear text, and in some cases, it may be one or more kinds of multimedia. To make that choice, a faculty member or student must have a command of the elements of multimedia and screen language and must understand how to use that command to create and disseminate knowledge." (p. 5)

Others have also noted that visual learning and portrayal may need special kinds of educational experiences [Lowe, 2000]. For instance, there is a need for visual creation literacy. Students lack opportunities to create their own visual work, they often end up copying versions the teacher creates or taking an illustration from the textbook. How can students learn to not only read but also write through graphical expression?

Latour [1986] suggests that visual explanation involves inventing objects which are mobile (moveable) but also immutable (not susceptible to change), presentable, read-able and combinable with each other. Latour calls these external objects of thought, "inscriptions". These are representations that exist in some material or electronic form and can be used for communication.

Kozma [1991] identified an important criterion for using a particular medium: "Learners will benefit most from the use of a particular medium with certain capabilities if the capabilities are employed by the instructional method to provide certain representations or perform or model certain cognitive operations that are salient to the task and situation and that the learners cannot or do not perform or provide for themselves." (p. 182)

The power of images is achieved when it extends or provides additional insights that otherwise would not be available. The utilization of visual representations may reconcile disparate knowledge structures as connected pieces or help establish new knowledge structures.

Despite the potential upside of visual representations there are cautions. There is evidence to suggest that if learners don't have sufficient prior knowledge, visual literacy skills, or if the images are not designed properly this can lead to erroneous or suboptimal learning [Richard E. Mayer, 2001; Watkins *et al.*, 2004]. However, it is clear from the previous discussion that understanding visual representations deserves greater emphasis in our instructional approaches, enter attribute activation theory.

## 3 Attribute Activation Theory

The previous discussion provides a backdrop to the proposed theoretical approach, and will be termed, the "attribute activation" theory. In selecting or creating portrayals, the mind has procedures for matching the dimensions of the problem (referent) with attributes of the visual. In certain circumstances, a visual representation may communicate dimensions of the information better than words. The mind may unconsciously sense that, and make a decision based on past experiences, as to the appropriateness of using a graphical portrayal. Is it possible to externalize this process and make it available for inspection and analysis?

The term, attribute activation, is not widely used in the literature. This is an invented term to describe how visual portrayals are processed. However, the literature alludes to it from a variety of theoretical perspectives. It is certainly not new; it has been broadly described in cognitive theories such as Anderson's Architecture of Cognition [Anderson, 1983]. In addition, Tufte [2000] and Massironi [2002] discuss the importance of visual explanation. However, the emphasis in the literature has focused on providing visual forms or manipulating visual forms. Much of the research on visual cognition involved students' recall, comprehension, and transformation of visual information. An area that needs more attention is how individuals select visual portrayals. What knowledge structures help identify the dimensions of the problem which link to appropriate attributes of the external representation?

Some researchers have addressed the concept of attribute activation in a round about way by creating a taxonomy of visual forms [Lohse *et al.*, 1994; Vekiri, 2002]. Lohse's study [1994] is of interest here because subjects rated a large number of images on various visual attributes. The purpose was to establish a visual classification system and Lohse does identify a number of useful representational types:

- Graphs – numeric information plotted on coordinate system
- Tables – information arranged in rows and columns – could be graphic, textual, or numeric information
- Time Charts – display temporal ordering in table form
- Network Charts – show relationships between items
- Structure Diagrams – illustrate physical description of an object
- Process Diagrams – describes the interrelationships between processes and or objects
- Maps – symbolic representation of physical locations – geographic information
- Cartograms – spatial maps that show quantitative data
- Icons – single representation of a picture or concept
- Photorealistic pictures – realistic images of an object or a scene

The images in question were also rated on 10 visual descriptor scales. This study demonstrates how previous researchers have attempted to identify the attributes of images. In this case, all the images were of existing representations, not of learner design. Vekiri [2002] identified a fewer number of categories (diagrams, maps, graphs, charts) but provided a more in-depth description of the attributes of those representations.

Cox [1999] has described attribute activation in terms of "matching external representations to the demands of the task" (p. 354). Studies by Mayer [1976] support this theoretical perspective, it was found that different forms of representation were better at communicating different aspects of the problem. O'Donnell [1992] found similar results with comparing learners using concept maps and textual descriptions. The key to creating or selecting appropriate portrayals is having the mind juxtapose the dimensions of the problem with attributes of the visual representation.

The previous discussion emphasized that selection of a representation form should not be a superficial choice. The same object can be portrayed in numerous ways depending on the purpose of the image [Massironi, 2002; Steed, 1994]. It is this multiplicity of representational forms that creates different worlds with different rules and intents. The creator of the image must make choices in terms of what can be omitted and what aspect of the information needs to be emphasized. Massironi raises an important concept in regards to understanding the psychology of images; that "we are part of an external world that exists independently of a mind that observes it" (p. 66). This is to suggest that there are as many realities as there are forms of cognitive representation. However, the concept of communication also suggests commonalities. Dialogue indicates that there are common cognitive structures upon which communication can be based. This line of logic suggests that images, like language, can become a means of sharing our ideas based on common understanding. The process of portrayal construction should ideally be an isomorphic relationship between the problem and the

externalized portrayal. Obviously there will be times when the relationship is not isomorphic but in either case this provides a platform for inferring cognitive structures and processes.

## 4 Attribute Activation as an Instructional Approach

The previous discussion laid the foundation for an instructional approach to the critique and creation of visual representations. To understand this approach to teaching visual representation, it is important to draw a distinction between dimensions of the information and attributes of the image. Attributes of the image are the elements of the image that communicate meaning. The dimensions of the information are the knowledge structures that are activated by the image in the mind of the viewer based on shared experience. The difference between these concepts can be depicted with an example, see Fig. 1.

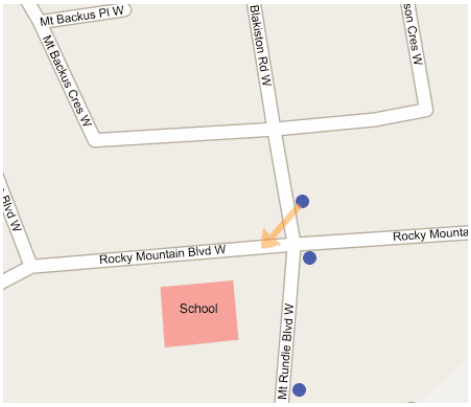


Figure 1 Aerial map showing location of school

An "Attribute Matrix" will help deconstruct the visual explanation in Figure 1. Table 1 is an example of how an attribute matrix may help identify the communicative properties of the image.

| Dimensions of Information | Attribute of Portrayal | Design and Layout Issues |
|---|---|---|
| current location in space | circle indicating position on map | contrast to make the circle stand out from the background (blue on white) |
| current perspective – direction of gaze | arrows pointing in direction of perspective (could also be confused with direction of movement – could be disambiguated with textual mediation) | arrow color to signify a different dimension of the information; the directionality of the arrow provides a clue to perspective |
| orientation of streets | the streets were represented with white areas bounded by lines and gray areas which represented developed real estate (gray) | labeling the street names and having the those a different colour (white) from the developed real estate (gray) helped to differentiate between different regions |
| position of the school | since this was a major landmark and perhaps the goal of the map, it is highlighted in red and its position on the map corresponds to its physical position in space | the color red makes the eye direct its attention to the most important landmark on the map - corresponding to the largest building or perhaps the goal or perhaps could correspond to the color of the building |
| other dimensions of the information are less important in way-finding (e.g. 3D information) | only the attributes relevant to way-finding are included - for instance, the position of sidewalks are less salient and might not be considered major landmarks | leaving out details reduces the cognitive load on the user and they are able to focus on the important elements in the representation - the landmarks |

The visual attributes in Figure 1 could act as interactive elements and if the user could click on the blue circle they see Fig. 2. This is a representation of what the person might actually see if they were positioned at the arrow and could be used in conjunction with the aerial map to give the audience a better sense of perspective.

Figure 2 Perspective Photo showing location of the school. This provides contextual details not available to the viewer in the aerial view

An Attribute Matrix is one approach to encourage reflection on the meaning of the representation. Another, approach is to layer the knowledge dimensions on top of the actual attributes of the image and then juxtapose that with the desired dimensions. This activity might help encourage students to consider attributes of the representation that would otherwise not be considered. Let us use another example to illustrate what this might look like. An example from the perspective of visual critique will prove useful. Then we will look at it from the perspective of visual creation.

Figure 3, is an article from the Lethbridge Herald (Sunday, October 12, 2003). The article attempts to communicate size by providing comparisons of the objects. In this case the size of the

elements is important and is intended to communicate dimensions of the information.

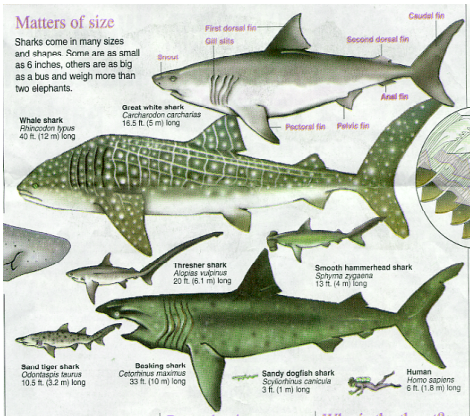


Figure 3 Matters of Size - Image obtained from the Lethbridge Herald (Sunday, October 12, 2003)

Look carefully at the information in Figure 3. Size is the dimension of the information that is salient. However, draw your attention to the human (bottom right hand corner) and compare that to the size of the white shark. This comparison immediately raises red flags (I have seen many documentaries and white sharks are no where near that large, relative to the human). Assuming the diver is 6 ft, that makes the white shark 35 feet long. The largest white sharks are only 20 feet. Obviously this image is not to scale yet this is an educational illustration, yet it fails to properly portray size, when the attribute of size is even in the title, "matters of size". One needs to be rigorous in how the dimensions of the information are communicated to ensure it is accurate. In this case there is a dissonance between the attributes of the image and the desired dimensions of the information, which could be misleading.

Effective visual literacy should encourage students to be more aware of the attributes of the image and how those relate to the dimensions of the information activated in the minds of the viewer. To this end one could use an attribute matrix as associated with Figure 1. However, with the advent of technology, it is conceivable for students to label the various components right on the image with lines linking the attributes of the image to dimensions of the information. Figure 4 is a more abstract artistic piece that communicates the notion of opposites.

Figure 4 Opposites – illustrative image created by the author

Figure 5 provides an annotated view of the image with attributes labeled and links to the dimensions of the information.


Figure 5 Opposites - annotated with attributes of the image and dimensions of the information

Figure 5 could be further enhanced with lines explicitly linking the textual descriptions of the attributes to the visual elements. In this static image there would be too many lines so it was left out. However, with rollover technology this could easily be accomplished. Each attribute could be a rollover so that when a pointer is hovering over an attribute a line points to the visual attribute in the image. This feature is termed “Attribute Rollovers”. In addition, for each attribute the corresponding design issues will be displayed in a popup window. This would create a multilayered interactive medium that cuts across the visual attributes from a number of different perspectives. Further refinements to this approach could be made by having students explicitly identify desired and extraneous aspects to both visual attributes and activated knowledge dimensions. This would accommodate alternative explanations and unintended interpretations of visual work. These could be shared as part of a discussion forum in which class participants post and discuss interpretations of their attribute activation portrayals.

Students often fail to see links between the dimensions of the information and the attributes of the images. However, attribute activation assignments could encourage them to address this issue more explicitly. They could be given a set of assignments that involved either the creation of Attribute Matrices or Attribute Rollovers. These could be shared and peer reviewed and then critiqued by the instructor. These exercises would then be incorporated into students’ visual experience and become a process they would turn to often in creating or critiquing visual representations. Attribute activation is a mental process that happens during most effective visual communication activities. It may not be called by this name but through conscious and unconscious processes this goes on. However, turning this into an explicit activity encourages students to slow down and systematically consider the important features of visual communication.

## 5 Implications for Visual Education

Attribute Activation turns visual understanding into a systematic approach that will encourage students to go beyond a superficial view of visual representation. The approach seems simplistic but through this rigorous method students will be more deliberate in seeing and articulating the attributes of visual representations. This approach facilitates an understanding of how meaning is constructed and in turn encourages a more effective visual critique or design process. Technology and new media play a key role in providing a platform for using this technique through attribute rollovers and design issue pop-ups.

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