Teaching novices design history via worked examples

Arianne J. Rourke

College of Fine Arts, University of New South Wales

Abstract
Art appreciation and criticism in the classroom is usually taught using problem-solving strategies that require the student to provide their own solution to open-ended questions on specific art examples, with little guidance or input from the teacher during this process. There are a number of advocates in art education who support the theory that discovery learning is an effective learning strategy (Dorn, 1998; Jausovec, 1994). Discovery learning in art and design education can be an effective learning strategy for students who have domain specific knowledge, however for students without such knowledge, supplying appropriate worked examples as suggested in this paper, should be a more effective method. Supported by Cognitive load theory and the visual literacy literature this theoretical paper argues that the use of effectively designed worked examples can assist first year university students to acquire domain specific schemas for identifying distinctive characteristics of a designer's work.

Introduction

This current research is based on the concept of Cognitive load theory and the literature of visual literacy and the influence this can have toward effective teaching of design history in higher education. This paper takes the stance that identifying a previously unseen design example is a problem-solving activity that novice learners, particularly those who lack visual literacy skills, find extremely difficult. Koroscik, Short, Stavropoulos and Fortin (1992) recommended that educators should not expect students to discover meaningful or accurate ideas about an artwork without teacher direction and input.

Some instructional material used in higher education often requires the learner to engage in a highly complex reasoning process that does not take into account whether the learner has stored in their long-term memory the information required to perform such tasks. Often this material when used in teaching, takes for granted that the learner has stored previous knowledge of the material being taught in their long-term memory that can be accessed via their working memory. Working memory has a limited capacity for simultaneously holding large amounts of novel information (Miller, 1956, Anderson, 1983; Baddeley, 1992; 2001). Teachers need to take this into account when designing instructional material for novice learners, such as first year university students studying design history for the first time.

Developing expertise in art and design

Being able to pitch instructional material to a student's level of knowledge and understanding is an important aim of education. In order to develop expertise in the disciplines of art and design, educators need to first assist students in acquiring the skills needed to comprehend relevant examples of art and design. Educators should provide learning opportunities that assist the learner to assimilate their prior knowledge to any new knowledge in order to promote schema acquisition that can assist with comprehension. Studies in art education have found that comprehension of art is reliant on both the nature of the visual stimulus and the viewer's cognitive structures or existing knowledge (Koroscik, 1982; Koroscik, Desmond & Brandon, 1985). According to the constructive theorist DiSibio (1982), comprehension is a cognitive process that requires the activation of an individual's prior knowledge. Koroscik, Desmond and Brandon (1985), have suggested that comprehending art involves a complex interplay between encoding its formal qualities and its semantic characteristics. Raney (1999) suggests that critical understanding, that most experts possess, requires guided study and discussion and 'informed judgement'.

According to Prawat (1989) students should be provided with the concepts and principles that are most likely to promote domain specific expert competence. Expert performance is acquired gradually. In order for students to improve their performance in an art related discipline, they will depend on the teacher's ability to provide a series of simple training tasks that the students can successfully master by repetition, while being provided with feedback and instruction (Ericsson, Krampe & Tesch-Romer, 1993). One method for doing this is to provide students with worked examples which is an instructional method Cognitive load theory advocates.

Cognitive load theory, worked examples and novice learning

Cognitive load theory (e.g. Paas, Renkl & Sweller, 2003; 2004; Sweller, 1988; 1989; 2003), has contributed widely to the fields of education and training. This theory takes into account human cognitive architecture and its role in processing information in short-term and long-term memory. In particular it addresses the importance of designing instructional material that considers the limitations of human working memory. This theory also puts forward the notion that effective "instructional material facilitates learning by directing cognitive resources towards activities that are relevant to learning rather then towards preliminaries to learning" (Chandler & Sweller, 1991, p.293).

Cognitive load theory suggests ways of improving instructional design in order to assist the learner in acquiring schemas so that the information that has been learnt can be permanently stored and automatically retrieved from long-term memory. Schemas or information networks consist of concepts that are building blocks of knowledge in a hierarchical network of lower order or less complex information units to higher order or more complex information units.

One instructional method that Cognitive load theory promotes is the use of worked examples for teaching novice learners new material. A large number of studies on instructional design have examined learning from worked examples, particularly in the fields of mathematics, physics and computer programming (e.g. Ward & Sweller, 1990; Paas & van Merriënboer, 1994; Carroll, 1994; Tuovinen & Sweller, 1999). Experiments conducted by Rourke (2006) reported in this paper differ from previous studies in that they apply both Cognitive load theory and the visual literacy literature towards testing two methods of instructional design

(worked example and problem-solving) for teaching design history in higher education, a focus not previously researched. A worked example can be defined as: an instructional method that provides a domain specific example to follow and study of a problem that includes a worked-out solution (often in steps). Worked examples direct the learner's attention to what needs to be learnt and in the case of teaching design history towards developing visual literacy skills.

Visual literacy and learning

In generic terms, visual literacy is defined as the ability to read visuals. It is also considered to be a universal attribute that is developed through acquiring a set of principles used for reading visual form (Boughton, 1986). Wileman (1980) defined visual literacy as the ability to 'read' and comprehend what is seen, and the ability to generate material that has to be seen to be understood. Visual literacy has also been defined as the "ability to construct meaning from visual images" (Giorgis, Johnson, Bonomo & Colbert, 1999, p.146). For the viewer to find meaning for example in an art image or design object, they need to comprehend basic elements of a universal visual language.

Visual education is concerned with visual communication that is developed through learning how to appreciate and critique art as well as through the practice of art making. Through the process of educating vision, skills for developing visually literate individuals can be encouraged. The "need to develop visual literacy in pupils...obviously touches on the need for them to be fluent in the use of symbols for demonstrating understanding as they evaluate and make art" (Cunliffe, 1992, p.146).

Berger (1972), writer of the popular art text 'Ways of Seeing', stated that: "images are more precise and richer than literature" (p.10) and as such images in the visual world could be 'read', once one learns various 'ways of seeing'. Teaching visual literacy involves students learning the 'language' of art as well as developing skills for deciphering visual syntaxes or codes in the visual world. However, this broad unfocused approach to learning visual material does not direct the viewer's attention towards what needs to be learnt.

There has been a number of studies that have examined the encoding and retrieval of information from pictures (Friedman & Bourne, 1976; Kunen, Green & Waterman, 1979; Mandler & Johnson, 1976; Mandler & Ritchey, 1977). The results from these studies are not easily generalised to visual art processing according to Koroscik (1982), who has studied the complexities of visual art processing specifically in relation to the characteristics of pictorial information processing. Koroscik (1982) discovered that prior knowledge, the amount of time allocated to studying the artwork, and the level of the task demanded, all affected students ability to learn visual material.

Koroscik, (1982) proposed that: "individuals with prior knowledge of visual art process more information than those who lack such information" (p.21). For students with specific knowledge of art have the schemas that allows them to process more information in working memory. The learner's level of expertise can have an effect on their ability to solve problems, similarly the problem-solving strategy of art critiquing can be a problem for the novice learner who lacks the schemas to effectively analyse a work of art. Worked examples can be designed to assist novice learners to develop the schemas needed to identify and analyse a work of art or design. When prototypes are included, which embody the main characteristics of a work, worked examples can also assist the novice learner with the semantic processing needed to fully comprehend a work of art or design.

Visual literacy and memory

Schnotz (2002) stated that the perceptual images created in picture comprehension are sensory specific because they link to visual modality and semantic processing is needed to understand a picture as opposed to just perceiving it. According to Kosslyn (1994) the proximity of these images to perception relates to the notion that visual images and visual perceptions are based on the same cognitive mechanism. Ullman (1984) stated that in perceptual processing, domain specific information is selected from cognitive schemata, which is then visually organized through automated visual routines. A number of studies have investigated 'visual sketchpads', which are the viewer's mental representation of a visual perception of a picture in the imagery part of working memory (e.g. Baddeley, 1992, Sims & Hegarty, 1997). To assist the learner in developing their 'visual sketchpads' in art and design education prototypes, which exemplify the main characteristics of a work, can be a useful instructional tool.

According to Solso (2003) 'prototypes' can be used in art to assist with the recognition of the central visual characteristics of the work. Solso (2003) discussed "prototypes as the abstractions of stimuli against which patterns are judged" stating that "it is possible, and far more economical, to store impressions that embody the most frequently experienced features of a class of objects" (p.230). He suggested that to conceptualise art and understand the classification of art periods and individual artists' styles, the process of forming cognitive categories in the form of both personal and knowledge schemata is the predominate way art knowledge is stored in long-term memory. According to Solso (2003), from the experience of viewing a typical exemplar of an art period, the viewer forms a general impression of the style, so when another work of the period is viewed it can be immediately 'recognized' as belonging to the same period as the 'prototype'. Solso (2003) stated that: "the formation of a prototypical memory is accomplished through perception of features that are recombined in memory" (p.233).

In order for educators to use visual exemplars effectively, it "requires sufficient understanding of how the human cognitive systems interacts" (Schnotz, 2002, p.114) with the visual stimuli. A number of studies have ascertained that instructional design that includes both verbal and pictorial information should be presented in a coherent manner with some semantic overlap (e.g. Carney & Levin, 2002; Mayer & Gallini, 1990). Well-designed instructional material should provide interconnection between verbal and visual information so that they enter working memory simultaneously (Schnotz, 2002). One method that assists with this process is the use of semantic cues, which can facilitate transfer by assisting the viewer in finding connections between the artwork's characteristics and the viewer's prior knowledge (Koroscik, Short, Stavropoulos & Fortin, 1992). Worked examples can be designed to include prototypes that contain appropriate semantics cues, which can assists the viewer towards identifying key characteristics of an art or design work.

Problem-solving versus Worked examples

Rourke (2006) experiments conducted in a realistic teaching environment tested the effectiveness of studying and practicing worked examples compared to completing problem-solving tasks. The design of the two experiments was the same, with both experiments having an Experimental group presented with worked examples and problems and a Control group presented with problems alone. Where the two experiments differ is that Experiment one was conducted with first year university students studying for a design degree and Experiment two

was conducted with second year university students studying for an art education degree. Both experiments used the same material to test which method, worked example or problem-solving, could best assist students towards recognising the main characteristics of a designer's work.

Both experiments were divided into three stages conducted over a three-week period of a university semester. Stage one of the experiment was a lecture with visual examples on five designers from the Art Nouveau or the early Modernist period (approximately 1880-1914). Stage two consisted of a practice session where the Experimental group received five worked examples and five practice exercises and the Control group received ten problem-solving tasks. In Stage three of both experiments both the Experimental group and the Control group completed a three-page test.

In the Experiment one, Stage two practice that used visuals of chairs, the Experimental group scored on average 41.25% better than the Control group after studying worked examples compared to completing problem-solving tasks. In the Stage three test, where students were required to match a chair to a designer, the Experimental group scored on average 15.4% better than the Control group. In the second and third page of the three page Stage three test, students were required to match the designers from the practice and page one of the test, to non-chair examples in order to test whether they had acquired the transfer skills needed to score well at this task. In this section of the Stage three test (questions 1,4,7,9), the Experimental group on average scored 25% better than the Control group and when required to list the characteristics of each design (questions 2,3,8,10), the Experimental group scored on average 6% better than the Control group.

The test scores for Experiment one were low however, which suggests that the material was too difficult for first year university students to learn, as demonstrated by the low results of the Stage three test (less than 50% could identify the chair designs on page one of the test; the averages for questions 1,4,7,9 were below 1; the averages for questions 2, 3, 8, 10 were below 2; questions 5 and 6 were not used in the results due to the ambiguity of the questions). These low scores could be explained by the fact that studying art in high school is not necessarily a prerequisite for studying art or design at university in New South Wales.

Experiment one has however provided preliminary evidence that the worked example effect can be obtained in the area of teaching design history in higher education. The next experiment was intended to further confirm this finding. Experiment two tested whether the results from Experiment one could be improved if the same material was presented to a more advanced group of students. It also tested whether students with more advanced visual literacy skill who study worked examples are better at applying the necessary transfer skills needed to identify non-chair examples (after studying only chair examples in the Stage two practice) than students completing problem-solving tasks.

In Experiment two, the Experimental group scored on average 33.75% better than the Control group in the Stage two practice after studying worked examples compared to completing problem-solving tasks. In the Stage three test where students were asked to match the chair to the designer, the Experimental group scored on average 35.5% better than the Control group. In the second and third page of the three page Stage three test, the Experimental group on average scored 64.4% better than the Control group when asked to identify the designer of non-chair examples (questions 1,4,7,9). When asked to provide a list of characteristics of the non-chair examples (questions 2,3,8,10), the Experimental group where on average 27.66%

better at this task than the Control group. The scores in Experiment two were substantially better than Experiment one, in the Experimental group more than 50% could identify the chair designs on page one of the test and the averages for questions 1,4,7,9 was 1.7; the averages for questions 2, 3, 8, 10 was 2.7.

The results of the experiments conducted by Rourke (2006) provides some evidence that students who have already acquired visual literacy skills find learning new material easier when provided with worked examples than problem-solving tasks. Students who lacked the necessary visual literacy skills, when provided with worked examples, had some success compared to students provided with problem solving tasks, however the group scores substantially increased when students had the necessary visual literacy skills.

The experiments reported in this paper provide results that contain important implications for teaching design history in higher education. Design history is usually taught via a lecture and tutorial format that includes student presentations often based on tutorial readings, as well as problem-solving exercises via visual example analysis. Students are expected to have previously acquired the necessary visual literacy skill to carry out these problem-solving activities and have a working knowledge of the elements and principles of design. Hence it is usually taken for granted that they can analyse and appreciate as well as identify designers and their work during problem-solving activities after being provided with information presented in a lecture format.

Students in their first year at university who are undertaking studies in design history related disciplines, need to be provided with learning tasks that further develop their competency in visual literacy. In order to effectively synthesise and apply prior and new knowledge to the discipline of design history, students need to acquire the schemas that combine domain specific knowledge with visual literacy skills. “What matters, both from the point-of-view of making and of reading expressive images, is that we have a working knowledge of symbols” (Cunliffe, 1992, p.149). Design history images are made up of semantic cues and it is these symbols that learners can be taught to identify.

Conclusions

According to Feldman (1982) art “is a language of visual images that everyone must learn to read” (p.5) and according to Boughton (1986) “visual communication relies upon a innate grammar of images that is learnable” (p.127). In today’s higher education climate, educators cannot take for granted that students have acquired these skills during their high school education. The Rourke (2006) research discovered that novice learners find it difficult to identify previously unseen visual examples without having acquired basic domain specific visual literacy skills, even when provided with the necessary information.

Feldman (1976) recognised the complexity and ambiguity of images when he stated that: “more than one valid reading of an image is possible. However there is a family resemblance among several readings that a single image is capable of supporting” (p.198). It is this concept that can be underpinned by Cognitive load theory in that worked examples that include well chosen visual examples that represent the work of a particular designer can be used as an instructional tool to direct attention to what needs to be learnt. The notion is that because of the limited capacity of working memory, the novice learner will benefit from instruction that takes this into account by reducing extraneous information not necessary for learning the required concept. For as Ward and Sweller (1990) stated: “it is clear that the important point

is not whether worked examples are presented, but rather whether cognitive load is reduced and attention is appropriately directed" (p.38).

The results of Experiment one suggest that students who have limited visual literacy skills require additional facilitated design experience that involves analyzing, critiquing and appreciating design examples within a variety of historical and theoretical contexts in order to fully benefit from worked examples that use previously unseen material. In particular similar subject-matter worked examples, could be used as a starting point to assist students towards acquiring the domain specific schemas needed to identify the features of a designer's work. As students acquire more advanced visual literacy skills through the study and practice of same medium worked examples, more complex worked examples can be introduced in order to promote transfer skills and hence a higher level of visual literacy.

The more experienced students in Experiment two, learnt to, as Carroll (1994) also discovered, "look beyond the surface features of the problem to the underlying structural similarities, a process that would facilitate construction of a base schema" (p.365) that assisted the Experimental group with transfer. As these students had previously acquired the ability to 'read' visual material, when provided with the essential knowledge they needed to learn, they could effectively apply this towards 'seeing' the differences and similarities between each different designer's examples. This ties in with previous research by Ross (1987; 1989), Ross and Kennedy (1990), and Paas and van Merriënboer (1994) who discovered that earlier experience had a major effect on later performance. This was because, according to Paas and van Merriënboer (1994), most learners relate new knowledge and experience to similar acquired knowledge and experience, despite the quality of the remembered examples.

Hence, as this research has demonstrated worked examples are an effective instructional tool for learning high element interactive material particularly for students who have already acquired the necessary visual literacy schemas needed for linking new visual material and information to previous knowledge. For students without these necessary skills, Kotovsky, Hayes and Simon (1985) suggested that novices should be provided with learning activities that can be carried out with 'nonautomated' rules. As Experiment one concludes, in order to identify the features of a designer's work, particularly where transfer skills were required, students need to automate the semantic cues, a process that proved difficult for students who had limited visual literacy skills.

The research conducted by Rourke (2006) provides evidence in a real classroom situation that supports the use of worked examples compared to problem-solving tasks to teach students how to identify the characteristics of a designer's work. According to Chandler and Sweller (1991) the "ultimate aim of any theory dealing with cognition and instruction must be that it generates new and useful instructional techniques" (p.330). In this case combining visual literacy instruction with worked examples for novice students is an effective combination for learning how to identify the characteristics of a designer's work, as was discovered in the results of Experiment two. A study by Ausburn and Ausburn (1978) also discovered that "the superficiality of pupil's comprehension of much of what they view, suggests that higher order visual literacy skills do not develop unless they are identified and taught" (p.288). This could be achieved by first introducing similar subject-matter worked examples then, as students acquire the necessary schemas for identifying these designs, worked examples of designs of different subject-matter could be introduced to promote both transfer skills and higher level visual literacy skills.

It is recommended based on the results of this research, that educators should adjust their instructional design to include worked examples that accommodate varying levels of visual literacy skills in order to avoid overloading the limited capacity of working memory of the novice learners when presented with new material to learn. This paper takes the stance that identifying a previously unseen design example is a problem-solving activity that novice learners, particularly those with limited visual literacy skills, find extremely difficult. New information that is presented to the novice as a problem to solve has proven to be an inadequate instructional method for facilitating schema acquisition (Ward & Sweller, 1990). Many studies of student learning in educational settings have indicated that the mental process of learning, which involves the construction and acquisition of schemas, are adversely hindered by poor instructional design (Cooper & Sweller, 1987; Sweller, van Merriënboer & Pass, 1998; Chandler & Sweller, 1992). Researchers have found that means-end problem solving is not a successful way for novices to learn (Owen & Sweller, 1985; Sweller, 1988; Ayres, 1993).

In contrast worked examples have been proven to be a successful instructional method for promoting schema acquisition in novice learners (Cooper & Sweller, 1987; Sweller & Cooper, 1985; Ward & Sweller, 1990). This study has suggested that visual literacy skills and in particular design history knowledge has a logic that can be learnt via effective worked examples.

References

Anderson, J.R. (1983). *The Architecture of Cognition*. Cambridge: Harvard University Press.
Ausburn, L. & Ausburn, F. (1978). Visual literacy: background, theory and practice. *PLET*, *15* (40), 291-297.
Baddeley, A.D. (1992). Working Memory. *Science*, *255*, 556-559.
Baddeley, A.D. (2001). Is working memory still working. *American Psychologist*, *56* (11), 851-64.
Berger, J. (1972). *Ways of Seeing*. London: British Broadcasting Corporation.
Boughton, D. (1986). Visual Literacy: Implications for cultural understanding through Art Education. *Journal of Art and Design Education*, *5* (1&2), 125-142.
Carney, R.N. & Levin, J.R. (2002). Pictorial illustrations still improve student's learning from text. *Educational Psychology Review, 14* (1), March, 5-26.
Carroll, W. M. (1994). Using worked examples as an instructional support in the algebra classroom. *Journal of Educational Psychology*. *86* (3), 360-367.
Chandler, P. & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8* (4) 293-332.
Cunliffe, L. (1992). Why a Theory of Symbols is Necessary for Teaching Art. *Journal of Art and Design Education*, *11* (2), 143-153.
DiSibio, M. (1982). Memory for disconnected discourse: A constructivist view. *Review of Educational Research*, *52* (2), 149-174.
Dorn, C.M. (1998). *Mind in art: cognitive foundations in art education*. Mahwah, N.J.: Erlbaum
Ericsson, K. A., Krampe, R.T.H. & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review. 100* (3), 363-406.
Feldman, E.B. (1976). Visual literacy. *Journal of Aesthetic Education*. *10* (3/4), 197-200.
Feldman, E.B. (1982). Art in the mainstream: a statement of value and commitment. *Art Education*. *35* (2), 4-5.

Friedman, A. & Bourne, L.E. (1976). Encoding the levels of information in pictures and words. *Journal of Educational Psychology: General*. *105* (2), 169-190.
Giorgis, C., Johnson, N.J., Bonomo, A. & Colbert, C. (1999). Visual Literacy. *Reading Teacher*. *53* (2), 146-153.
Jausovec, N. (1994). Problem finding and empathy in art. In Runco, M.A. (Ed.), Problem-finding, problem-solving and creativity. Norwood, N.J.: Albex.
Koroscik, J.S. (1982). The effects of prior knowledge, presentation time and task demands on visual processing. Studies in Art Education. 23 (3), 13-22.
Koroscik, J.S., Desmond K.K. & Brandon, S. M. (1985). The effects of verbal contextual information in processing visual arts. Studies in Art Education. 27 (1), 12-33.
Koroscik, J.S., Short, G., Stavropoulos, C. & Fortin, S. (1992). Framework for Understanding Art: The Function of Comparative Art Context and Verbal Cues. Studies in Art Education, 33 (3), 154-164.
Kosslyn, S.M. (1994). *Image and Brain, the resolution of imagery debate*. Cambridge, M.A: MIT.
Kotovsky, K., Hayes, J.R. & Simon, H.A. (1985). Why are some problems hard? Evidence from Tower of Hanoi. Cognitive Psychology. 17 (2), 248-294.
Kunen, S., Green, D. & Waterman, D. (1979). Spread of encoding effects within the nonverbal visual domain. *Journal of Educational Psychology: Human Learning and Memory, 5* (6), 574-584.
Mandler, J.M. & Johnson, N.S. (1976). Some of the thousand words a picture is worth. *Journal of Educational Psychology: Human Learning and Memory*. *2* (5), 529-540.
Mandler, J.M. & Ritchey, G.H. (1977). Long-term memory for pictures. *Journal of Educational Psychology: Human Learning and Memory*. *3* (4), 386-396.
Mayer, R.E. & Gallini, J. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology*, *82* (4), 715-726.
Miller, G.A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review. 63*, 81-97.
Paas, F. & van Merriënboer, J. (1994). Variability of worked examples and transfer of geometrical problem-solving skills: A cognitive-load approach. *Journal of Educational Psychology*, *86* (1), 122-133.
Paas, F., Renkl, A. & Sweller, J. (2003). Cognitive Load Theory and Instructional Design: Recent Developments. *Educational Psychologist*, *38* (1), 1-4.
Paas, F., Renkl, A. & Sweller, J. (2004). Cognitive Theory: Instructional Implications of the Interaction between Information Structures and Cognitive Architecture. *Instructional Science*, *32*, (1/2), 1-8.
Prawat, R.S. (1989). Promoting access to knowledge strategies and disposition in students: A research synthesis. Review of Educational Research. 59 (1), 1-41.
Raney, K. (1999). Visual Literacy and the Art Curriculum. Journal of Art & Design Education. 18 (1), 42-47.
Ross, B.H. (1987). This is like that: the use of earlier problems and the separation of similarity effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. *13* (4), 629-639.
Ross, B.H. (1989). Distinguishing types of superficial similarities: Different effects on the access and use of earlier problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15* (3), 456-468.
Ross, B.H. & Kennedy, P.T. (1990). Generalizing from the use of earlier examples in problem-solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition. 16* (1), 42-55.

Rourke, A, J. (2006). *Cognitive load theory and the use of worked examples in design history to teach novice learners to recognise the distinctive characteristics of a designer's work.* EdD, Kensington: The University of New South Wales.
Schnotz, W. (2002). Towards an integrated view of learning from text and visual display. *Educational Psychology Review. 14* (1), March, 101-120.
Sims, V.K. & Hegarty, M. (1997). Mental animation in the visuospatial sketchpad: evidence from dual task studies. *Memory and Cognition, 25*, 321-332.
Solso, R.L. (2003). *The Psychology of Art and the Evolution of the Conscious Brain*. Cambridge, Massachusetts & London: MIT Press.
Sweller, J. (1988). Cognitive load during problem-solving: Effects on learning. *Cognitive Science, 12* (2), 257-285.
Sweller, J. (1989). Cognitive technology: Some procedures for facilitating learning and problem-solving in mathematics and science. *Journal of Educational Psychology*. *81* (4), 457-466.
Sweller, J. (2003). 'Evolution of human cognitive architecture', in Ross, B. (Ed.), *The Psychology of Learning and Motivation.* Academic Press: San Diego
Tuovinen, J. & Sweller, J. (1999). A comparison of cognitive load associated with discovery learning and worked examples. *Journal of Educational Psychology, 91* (2), 334-341.
Ullman, S. (1984).Visual routines. *Cognition, 18* (1/3), 97-159.
Ward, M. & Sweller, J. (1990). Structuring effective worked examples. *Cognition and Instruction, 7* (1), 1-39.
Wileman, R.E. (1980). *Visual Thinking*. New York: Hasting House.